DEPARTMENT OF TRANSPORTATION

Evaluation of a Central Traffic Signal System and Best Practices for Implementation

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Detailed Intersection Control Information (ICI), including timing, phasing, geometric, and demand attributes, is an increasingly important resource for researchers, consultants, and private sector companies for many applications, including development of traffic models and technologies such as vehicle information or automation systems. While this information has historically been difficult to distribute due to variations in the availability and format across the numerous jurisdictions that operate signals, recent trends toward increased use of Central Traffic Signal Control Systems (CTSCSs) have made creation of a unified, standardized system for organizing ICI more feasible. To help work toward this, in this project researchers interviewed and surveyed signal operation engineers and transportation modelers throughout Minnesota to learn how different jurisdictions manage information relating to their signals and how this information is used for operations and planning. With this information, researchers developed a comprehensive Unified Set of Intersection Control Information (U-ICI) that contains all the information required to describe the control of an intersection in a format that is readable by both humans and machines. Along with this, researchers evaluated the availability of this information and the feasibility of using existing CTSCS applications to store this information. While the researchers conclude that it is not feasible to use these applications to store all of the U-ICI, the applications will likely make the process of implementing and populating such a system easier. Though some information may be contained in formats that will require manual effort to digitize, the up-front effort to do so will be a worthwhile pursuit.

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ATSPM – Automated Traffic Signal Performance Measures

ATMS – Advanced Traffic Management System

CTSCS – Central Traffic Signal Control System

CU – Controller Unit

DDI—Diverging Diamond Interchange

GIS – Geographic Information System

ICI – Intersection control information

MnDOT – Minnesota Department of Transportation

NEMA – National Electrical Manufacturers Association

NTCIP – National Transportation Communications for Intelligent Transportation Systems Protocol

UDOT – Utah Department of Transportation

EXECUTIVE SUMMARY

Detailed Intersection Control Information (ICI), including timing, phasing, geometric, and demand attributes, is an increasingly important resource for researchers, consultants, and private sector companies for many applications, including development of traffic models for planning purposes and emerging technologies such as vehicle information or automation systems. Historically, this information has been difficult or impossible to distribute due to the wide variation in availability and storage formats across the numerous jurisdictions that operate signals.

More recently, a number of agencies have begun to adopt Central Traffic Signal Control Systems (CTSCSs), such as Intelight MaxView, Econolite Centracs, and Siemens TACTICS, to help streamline the management of their traffic signals. The move toward these systems and similar systems for automating the collection of Signal Performance Measures (SPM) has led to a growing number of agencies to digitize and standardize the systems and formats they use for storing ICI. Despite this, the varying needs of these agencies and the limitations of these systems mean that there is still a lack of a unified, standardized format for representing ICI. While these systems provide good support for storing ICI that is directly related to the intersection Controller Unit (CU) and some of the associated geometric information, obtaining the full set of ICI for an intersection still requires use of other documents to obtain the detailed geometric information that is required to correctly interpret the control information used by the CU. The demands of future applications, however, require a more comprehensive ICI storage and distribution solution.

This research project was intended to work toward a solution to these problems through two tasks. First, researchers sought to develop a comprehensive, unified set of ICI (U-ICI) that could be used to represent all of the relevant control information at an intersection in a format that is readable by both humans and machines and assess the availability of this information. Second, researchers evaluated the CTSCS and Signal Performance Measures (SPM) applications in use by the Minnesota Department of Transportation (MnDOT) to determine the feasibility of using these systems for storing or obtaining the information required by the U-ICI. Together these two tasks were meant to inform the potential future effort of implementing a system for storing the U-ICI from intersections owned by multiple agencies across the Twin Cities metropolitan area, intended for the second phase of this project.

To complete Task 1 of this project, identifying the contents and developing the format of the U-ICI, researchers worked with signal operations engineers and transportation model builders to identify the common practices for managing, distributing, and using ICI. Through collaboration with the MnDOT signal operators on the project's Technical Advisory Panel (TAP), researchers developed two separate survey instruments for soliciting this information from a large group of stakeholders. One survey, devised for obtaining information on how signal operators manage, store, and distribute their ICI, was sent to 153 signal owners and operators, each representing a unique jurisdiction in the state of Minnesota. This survey received 42 responses that helped describe how agencies of varying sizes and infrastructure managed their information, informing the assessment of the availability of ICI and the degree of effort required for implementing a regional database of ICI. A second survey, developed to obtain information about the various uses of ICI, was sent to 68 designers, modelers, and planners who have worked frequently with MnDOT signal information, and 25 responses were received. Along with these surveys, researchers also interviewed a select group of signal operators and transportation modelers to obtain more detailed information than could be obtained through the surveys.

With the information obtained from these surveys and interviews, along with researchers' experience working with signal control systems and transportation models, researchers used a number of example intersections of varying complexity to drive the identification and categorization of the parameters of the U-ICI. To help readers understand the parameters and the relationships between them, a full example of the U-ICI was developed for a Diverging Diamond Interchange (DDI), a complex type of intersection that can be difficult to represent with traditional intersection models, located in Rogers, Minnesota. Along with this, researchers developed a relational database schema for containing the U-ICI set in a machine-readable format. The resulting product of this task, presented in detail in Chapter 3 of the project report, represents a starting point for the development of a system for standardizing the management and availability of ICI across jurisdictions in a way that is both realistic and satisfies the needs of those who wish to use this information.

For Task 2 of this project, researchers evaluated the feasibility of using existing CTSCS or SPM applications for storing the U-ICI and developed recommendations of best practices for implementation of such a system. This effort focused on the applications used by MnDOT, namely Intelight MaxView (a CTSCS), and the Automated Traffic Signal Performance Measures (ATSPM) system developed by the Utah Department of Transportation (UDOT). To evaluate the possibility of using these systems, researchers worked to understand not only how they work from the perspective of the users but also the underlying details of how they manage information. This involved working with MnDOT signal operations engineers to examine how they use these systems and what information they stored in them, reviewing the available software documentation from the developers, and examining the relational database structure used by the programs to store data. In the case of MaxView, researchers also worked with Intelight, the software vendor, to obtain a trial installation of the system that was set up to administer controller units provided for the project by MnDOT and Intelight.

Through this work and direct communication with the software developers, researchers determined that neither MaxView nor the ATSPM system could be used to store the entire U-ICI. While both systems do contain much of the information in the unified set in database tables in a readable format, they are missing some of the detailed geometric information that is critical to understanding the intersection control. The structure of each database is also very application-specific and not well suited for general purpose information storage. Finally, and most importantly, there is a lack in both systems of readable signal programming information of the kind used by the CU. In the case of ATSPM, much of this information is absent simply because it is not necessary for the application to function. MaxView, by contrast, does contain this information, as it is required to program signal controllers; however, it is not readable by anything besides MaxView. For various reasons, the signal program information for a controller is contained in a binary serialized object with a proprietary format, referred to as a "Binary Database." Reading this information would therefore require a dedicated translation tool developed by Intelight, something that has been considered but with no immediate plans to do so.

Given these facts, researchers recommend a custom solution for implementing a centralized ICI warehousing system. Because of the limitations of CTSCSs such as MaxView, expanding such a system to meet the required functionality for storing the U-ICI would require active involvement from the developers to not only add the additional information but also to develop interfaces between the systems provided by different vendors. By contrast, a custom-built, centralized cloud repository for managing U-ICI would only require the vendors to develop tools for exporting the information they have in the U-ICI format, a much simpler task. A system like this would also be preferable over an existing CTSCS because it could reside outside of any particular agency's firewall, eliminating the complications caused by existing access restrictions that have made inter-agency ICI exchanges difficult.

The main expense in time and effort for building a cloud repository of U-ICI is in the development of the utilities for exporting information from CTSCS applications to the cloud repository in an organized way, as well as the user interface for this repository that allows querying information from selected intersections. Deploying and maintaining this repository, by contrast, would be a relatively simple task. Aside from the tools for exporting ICI, which must be developed by the vendors of the individual CTSCSs, there must also be utilities developed to handle the automatic or scheduled synchronization of information between each jurisdiction's system and the cloud repository. Designing and developing such tools and their interfaces would be the primary effort of the second phase of this project.

The other significant effort that would be required to implement a regional repository of U-ICI is in digitizing the remaining information in the unified set that is not currently stored in a machine-readable format. This information, which currently resides in paper records, spreadsheets, construction plans, and similar formats, would need to be manually entered into the cloud repository. Though it might constitute a large up-front effort, keeping the information updated would constitute a small fraction of this original effort. In the case of larger agencies that already use a CTSCS, the only data that would need to be entered manually are the detailed geometric attributes, not used directly by the controller or CTSCS, typically residing in construction plans. Given recent developments in the area of connected vehicles, however, much of this work needs to take place anyways to support the development of intersection-related applications. Indeed, in discussions that took place during the course of the project, it was learned that Intelight is initiating changes in MaxView to allow the input and storage of some of this information due to customer pressure. Though these changes are largely driven by other clients in other states, meaning that it is unknown exactly how much of the full U-ICI set from this project will be satisfied by these changes, it is still nonetheless a good indication of the direction of the industry.

The researchers hope that the work performed in this project produced an organized and comprehensive format for storing and transferring intersection control information that contains most, if not all, of the information required by the various stakeholder groups and demystified the resources and effort required to establish a repository for this information without compromising the security of any operational system.

CHAPTER 1: INTRODUCTION

Signalized intersections are a critical component of transportation infrastructure and have a very important role in the safety and efficiency of a road network. Because of this, detailed information describing these intersections has become increasingly desired by researchers, consultants, and traffic information providers for applications from modeling the impacts of construction projects on a regional network to emerging technologies such as the display of real-time signal status information in in-vehicle information systems. Intersection Control Information (ICI), including the geometry of intersections, the programming of signal controllers, and the demand served by an intersection are all essential to these applications; however, variations in the systems and practices employed by the countless number of agencies that operate signalized intersections makes obtaining this information for even a small number of intersections difficult or even impossible at times.

While the advancement of electronic microprocessors, vehicle detection technologies, and standards governing the design of signal controllers and cabinets have made operating and maintaining signals easier over recent decades, many improvements can still be made to make the distribution of ICI easier for both those who manage signalized intersections and those who use this information. Though larger agencies generally have well-established methods for responding to information requests that make this process easier, the varied systems and practices used by each agency make obtaining information from different agencies a significantly different process. Beyond this, the wide variety of geometric designs, controller hardware, and methods for implementing control features means that even collecting information for multiple intersections managed by the same organization can yield varied results. Together, these issues result in information requests that typically require significant manual effort both on the part of those providing the information and the people using it.

Despite these difficulties, recent technological trends have begun to reveal potential avenues for addressing these issues. The widespread adoption of standards governing the design and operation of traffic controller assemblies (NEMA TS 2 and Caltrans TEES) and device communication protocols (NTCIP 1202) have provided a workable framework for unifying how ICI is represented and implemented. Since the development of these standards, hardware and software vendors have increasingly adapted their technology to work within the definitions of the standards in response to demand from their customers. In addition to this, the accelerating development and deployment of connected vehicle technologies and consumer demand for data-driven applications have put pressure on the industry to establish methodologies for automating the dissemination of information from infrastructure. While the confluence of these factors has made it both realistic and necessary to do this, the large scale of the changes required along with the relatively slow turnover of infrastructure technology means that there is still significant work ahead.

1.1 PROJECT OBJECTIVE

The goal of this project is to develop guidance for collecting, representing, and importing intersection control information that can be used by MnDOT and other local jurisdictions to make these processes more efficient. This will not only benefit the users of this information, who will save time and effort by having access to data in a format that is more easily read by the programs they use, but also signal operators themselves, who will save time and effort in responding to information requests. The process of developing this guidance falls into two main tasks. First, to understand what is needed to collect, store, and distribute information describing any possible intersection, research must be conducted to identify a unified set of intersection control information that is both feasible to collect and contains all information that might be required for the wide variety of applications that needs ICI. Second, to minimize the effort needed to develop the system that is ultimately recommended, the capabilities of existing management tools used by MnDOT and other local agencies must be investigated to determine whether they are sufficient for this application, or whether a custom solution will be needed.

This report describes the findings of these two tasks, as well as the work that was performed to reach these findings. Over the course of this project, researchers obtained information from signal operators at MnDOT and many of the cities and counties that manage large numbers of traffic signals in the Twin Cities metropolitan area. This process involved the distribution of a survey to collect information on the practices of these agencies, detailed interviews with a subset of these agencies, and surveying local transportation modelers to understand how they use ICI. Along with this, researchers worked with the developers and users of centralized signal management tools used by MnDOT and other local agencies to understand the capabilities of these tools and determine how they might be used to satisfy the specifications identified by this project. The result of this work includes the unified set of intersection control information along with options for how this information could be collected and stored, providing material for a full work plan outlining how such a system and the associated change in practices could be implemented.

1.2 RELEVANT PRIOR EFFORTS

The first attempt that we are aware of to assemble traffic signal control information on a metro-wide scale was made in 2009 for a project titled “Access to Destinations: Arterial Data Acquisition and Network-Wide Travel Time Estimation (Phase II)”, led by Dr. Gary Davis. The first phase in that project had shown, through modeling, that including signal timing information greatly increases the travel-time prediction accuracy on arterial streets and made the case for a metro-wide Geographic Information System (GIS) containing all the signal timing information. With the help of Minnesota Traffic Observatory (MTO) engineers, signal timing data was harvested from most of the counties, major townships and MnDOT.

In 2009, few jurisdictions utilized the same traffic signal controllers or managed their signal information in a similar way. For example, Hennepin as well as MnDOT utilized Econolite controller. The city of Saint Paul utilized Safetran 170 controllers (Caltrans C1 platform), while Minneapolis used a variety of controllers--including mechanical-analog and electro mechanical. As a result, signal-timing data was provided in many different formats (paper, spreadsheet, software dependent-proprietary) with varying levels of completeness in their information, and representations of signal timing characteristics. Other strategies that made assembling a global “default” format difficult and time intensive were the protected turning movements among many arterial intersections and the number of separate timing plans that differ considerably throughout the day to reduce delay.

Each jurisdiction follows a variation of the National Electrical Manufacturers Association (NEMA) dual ring structure. For example, Saint Paul flips the NEMA convention upside down. Saint Paul utilizes twelve different conventions depending on the intersection approach geometry and number of phases utilized within the controller (RS170 type controllers). Others follow the diagram with a main-LEFT, minor-RIGHT ring barrier convention and so on. The take-away from this experience is that, because of the variety of formats in which the signal timing data is supplied, a largely manual and expensive process is utilized to tabulate most of the data into a unified container. Naturally, since this container is designed to serve a specific research project, not all information was included nor were any plans implemented to keep it updated.

The experience from the Access to Destinations project greatly highlighted the need for unified procedures in regard to coding signals and showed that a common container where this information can be stored and maintained is warranted. If such a resource were available, the quality of the construction staging project for the years 2017 to 2020 would have been considerably better since a lot of effort was spent to develop a Twin Cities Mesoscopic DTA simulation model, but none of the traffic signals simulated had real timing information. Instead, due to the difficulties previously outlined in addition to budget/time constraints, global defaults for the signals in the network were used. In a parallel project titled "Framework and Guidelines for the Development of a Twin Cites Mesoscopic DTA Model" undergone by the Minnesota Traffic Observatory (MTO), the need for easily accessible traffic signal information was identified both by local consultants involved in modeling as well as by MnDOT engineers, on the client side. During the course of that research project, an attempt was made to bulk load all the MnDOT traffic signal information stored in Synchro files into another traffic simulation software package. Unfortunately, because the method followed in the development of these Synchro files only considered the needs of the MnDOT Metro Signal Operations unit, small pieces of information, irrelevant to the needs of the aforementioned unit, were omitted rendering the entire cache of information not suitable for use with traffic simulation applications. At least not without considerable manual intervention.

All of the previously mentioned cases highlight the need to establish formal guidelines controlling the collection, archiving, storage, and dissemination of signal control information. This need will grow exponentially as the avenues of communicating real-time information and guidance to drivers on the road become an expected service, not the novelty it is today.

CHAPTER 2: STAKEHOLDER INPUT

To ensure that the end result of this project was as useful and relevant to practitioners as possible, a significant portion of the effort expended went towards gathering information from stakeholders to understand the practices of agencies that operate signals, the systems they use in their work, and the needs of people who regularly need access to accurate ICI. This process was driven largely by the systems and practices used by MnDOT signal operations and researchers' own experience as modelers, but additional work was performed to enhance the depth and breadth of this knowledge. This section describes the methods that were used to obtain information, the people and organizations that helped provide it, and the findings that influenced the later work of the project.

2.1 FUNCTIONAL SPECIFICATIONS

From the beginning of the project, researchers were aware of a number of important specifications that the system would need to meet in order for it to be a useful resource for the variety of people who need access to ICI. Perhaps the most significant requirement was that the system should store all the necessary information to describe the control of any intersection, including geometric information, controller program information, detection, and so on, in a machine-readable format in a single, centralized location. Currently, obtaining ICI for even a single intersection is a process that requires a considerable amount of manual effort, as there is little standardization in what formats ICI should be stored in, how the information should be encoded, and how it can be obtained. This makes large scale development of high-resolution models very costly and at times infeasible. If, by contrast, there was a standardized, machine-readable format for storing ICI, it could be more easily imported into modeling programs and greatly simplify the process of constructing or updating these models.

The other major requirement of the project was that the system must also be feasible to keep updated with the latest information from all agencies in the state. This meant that the information going into the system must be readily accessible by signal operators so they can be reasonably expected to put it into the system. Information that is not typically used by signal operators, even if useful, would need to be obtained by other means. It must be noted though that researchers did not consider a lack of digital records to be a significant barrier to keeping the system updated. In this case, the benefit that a unified system for storing ICI would provide was considered to outweigh the costs of manually importing information from paper records, which would primarily be an upfront, non-recurring cost of developing such a system.

Together, these requirements ensured that the recommendations produced by this research would be broadly useful into the future. These requirements were considered throughout the process of soliciting stakeholder input and were heavily influential on the ultimate formulation of recommendations. The following sections describe the findings that resulted from the information gathering process and how they relate to these requirements.

2.2 SIGNAL OPERATOR SYSTEMS AND PRACTICES

2.2.1 Information Gathering

To help researchers better understand how signal operators manage their systems and the records they keep, several meetings were held to allow researchers the opportunity to examine the systems used by MnDOT. Shortly before the project started, MnDOT acquired and migrated their systems to MaxView, a Central Traffic Signal Control System (CTSCS) that is designed to ease the task of managing large numbers of traffic signals. Because this system possesses many of the features of the system envisioned by this project, it was important for researchers to become familiar with MaxView and how it was used by agencies that operate signals. Though MnDOT is the largest organization using this system in the state, agencies such as Hennepin County, Dakota County, the City of Bloomington, and others have also migrated to this system, with others planning to follow.

As part of the information gathering process, researchers worked with MnDOT signal operators to understand how they worked with MaxView, determine what information it contained, and what information could be accessed via the graphical interface. Researchers also attended a MaxView Users' Group meeting, attended by local users of the system and the software vendors, to provide further knowledge. To explore the system more deeply, researchers also coordinated with Intelight, the company that develops MaxView, to obtain a trial version of the software for inspection and experimentation using real signal controller units. Throughout the process, researchers communicated extensively with Intelight to understand how their system works with controllers and what data is currently or potentially available, something that was very beneficial in reaching the findings presented in Chapter 4.

In addition to MaxView, MnDOT has also recently begun working with another centralized system designed to help signal operators: the open-source Automated Traffic Signal Performance Measures (ATSPM) system developed by the Utah Department of Transportation (UDOT). This system is more focused on collecting real-time data from signal controllers to evaluate the performance of signal programming, however it is still related to the goals of the project. Similar to the work done with MaxView, researchers also worked with MnDOT signal operators to see how this system was used. Along with this, researchers also took advantage of the numerous resources available that describe how the ATSPM system works and how it manages data, including reports, webinars, and UDOT's own public ATSPM portal.

While the systems used by MnDOT were the most influential on the project, because the unified system was envisioned to be statewide researchers made an effort to learn more about the systems used by other agencies to operate their signals. Table 2-1 presents a summary of the systems used by several of the largest signal-operating agencies in the Twin Cities metro area, along with the number of signals they operate. As can be seen in the table, while many of the agencies use the same system, there is still some variation. The most notable of these is the City of Minneapolis, which mostly uses Siemens controllers for their signal and manages them using Siemens' TACTICS CTSCS, and whom researchers met with specifically to learn more about their practices in detail. A number of agencies also still use Aries, which is a closed-loop management system released in 1996 by Econolite for managing their controllers.

Table 2-1 Summary of signal management systems used by agencies in the Twin Cities metro area. Based on data collected by Alliant Engineering, Inc.

Agency	CTSCS System?	Type of System	Year of Installation	Total # Signals	Signals managed on system
City of Minneapolis	Yes	TACTICS & Spinnaker	2013	~810	~780 Siemen's on TACTICS, ~30 PEEK's will be on Spinnaker
MnDOT	Yes	MaxView	2016	702	401
Hennepin County	Yes	MaxView and Aries	2015 (Demo version)	~400	16 on Maxview, ~350 on Aries
City of Saint Paul	Yes	Centracs	2012	387	350
Dakota County	Yes	MaxView and Aries	2017	200	50
Ramsey County	Looking to acquire	Aries	NA	200	200
City of Rochester	Yes	TACTICS	Unknown	150	127
Washington County	Yes	Aries and Miovision	Aries 15+ years, Miovision test 2015	78	~90%
City of Bloomington	Yes	MaxView	Sept/Oct 2017	73	21 currently, 42 by end of year, 73 over time
Scott County	No	Aries	--	50-70	Most
Carver County	Looking to acquire	Aries	NA	30-50	NA

2.2.2 Summary of Findings

The infrastructure required for a modern network of signalized intersections to operate comprises many interconnected layers of hardware and software distributed over large geographic areas. The most essential parts of this are the signal hardware, including signal heads, masts, wiring, controller cabinets, and the controller units, the specifics of which vary depending on the intersection geometry, the demand being served, the agency operating the signal, and the age of the signal. On top of this, more advanced intersections can have vehicle detection systems or have their control coordinated along with other nearby intersections.

While an individual signal, at the minimum, still only requires the basic hardware and a simple program to operate, the advent of modern communication technology has allowed large numbers of signals to be connected to a network managed by the road authority for centralized control via one of many commercially available traffic signal management systems. This allows for more efficient management of signals that can better respond to the changing demands of the traffic network; it also means there is more information required to accurately represent the way a signal operates at any given point in time, and this information can change frequently. Variations in the systems and practices used at any particular agency also means that the same information can be stored and transmitted in different formats that add to the difficulty of using this information.

Because of the long operating life of an intersection, along with the time scale over which an intersection is designed and constructed, records on the current information describing an intersection can be in several different formats distributed over a number of physical or virtual locations. Geometric information, such as lane and crosswalk dimensions, in-pavement detector locations, pedestrian buttons, and so on are generally set during the construction design phase, meaning that this information is often located in construction plans. This information may also change, either temporarily if there is construction occurring that affects the intersection layout, or permanently if the intersection is redesigned. By contrast, program information, since it must change to adapt to the traffic using the intersection, is usually in a different format that allows for regular modifications. For larger agencies that manage large numbers of signals, this information is often managed by a Central Traffic Signal Control System (CTSCS) or Advanced Traffic Management System (ATMS), software that centralizes the administration of signal controllers and communicates with the controllers via a network. For smaller agencies, however, program information may be entered into controllers directly either over a network or by visiting the cabinet in person. Records of the active program information can be kept in a variety of formats including spreadsheets, PDF files, paper records, and logs located in the cabinet. The same is also true for the locations of detectors set in software, as is the case with vision- or radar-based detection technologies.

Finally, while signals operated by larger agencies are usually centrally managed, information security policies often lead to access restrictions that can impeded distribution of ICI, even to other agencies that might operate nearby signals. This presents a significant challenge to developing a more efficient distribution system, as any system would need to conform to the requirements of the organizations involved. There are options for working around this, however they generally involve the use of externally hosted systems that are capable of receiving data that is “pushed” by the secure system on an agency’s network, preventing the use of existing features of the common CTSCS’s for providing controlled access to external parties.

2.3 USE OF INTERSECTION CONTROL INFORMATION

While researchers were not as familiar with the common practices of signal operators, by contrast they have considerable experience as transportation modelers, having spent years developing models using several widely used commercial modeling programs. This knowledge was helpful in reducing the amount of effort required to determine what ICI is commonly needed by modelers to do their jobs. This section briefly summarizes these needs and how they affect the recommendations of the project.

As laid out in the functional specifications, just as important as the needs of signal operators are the needs of those who regularly use intersection control information. A wide variety of transportation planning and design activities rely on accurate ICI to develop computer models of transportation networks and make key decisions regarding the scheduling of construction projects, redesigning infrastructure, and many other activities with wide-reaching impacts. Signal retiming is often also performed by consultants who need ICI to develop their models. Depending on the resolution of the model in question, models can require everything from basic demand estimates to detailed descriptions of intersection geometry and signal programming. Obtaining this information for an intersection currently requires finding the contact information of the agency that operates the signal, manually requesting the information, and using the resulting documents, typically a combination of signal timing reports, construction plans, and any number of agency-specific document formats, to input the information into a model. These programs often include features for importing information from common formats, such as Synchro files containing signal timing information, providing some potential formats that could be included as options for exporting data from the unified system.

In addition to modelers, a variety of other players are increasingly interested in obtaining intersection control information for their purposes, largely driven by wider trends in the industry towards a more interconnected, data-driven transportation network. These include existing travel information providers like Google and INRIX, as well as developers of connected and autonomous vehicle applications that are preparing for fundamental changes to the transportation network that are rapidly approaching. The nature of these applications, many of which run in real-time, would require that ICI be provided using an online system that is kept updated at all times.

2.4 SURVEY INSTRUMENTS

Early on in the project, it was decided that a survey should be distributed to a variety of stakeholders to collect information about how ICI is stored and used. This was meant to help fill in any gaps in the knowledge of researchers and the signal operators they worked with most closely, as well as to get some idea of the feasibility of implementing the unified system envisioned by this project.

2.4.1 Developing Survey

The survey was developed by researchers with close involvement from the project's Technical Advisory Panel and Technical Liaison. After beginning with a rough list of the groups that might have information relevant to the project and an outline of the questions to be asked, researchers worked to narrow the groups down based on their common needs or the information they have. To optimize the information obtained, it was known early on that multiple surveys would need to be developed, and after some deliberation it was decided that two surveys would be developed: one sent to representatives of organizations that own and operate signals, and one sent to modelers and others who frequently use ICI. The questions in these surveys, which can be viewed in full in Appendices A and C, were developed by researchers and MnDOT signal operations staff based on their existing understanding of signal operations and the needs of modelers. In addition to this, the survey for modelers was also made available for comments by members of the North Central Section of the Institute of Transportation Engineers (NCITE) Simulation and Capacity (SimCap) Committee, which includes many experienced transportation modelers who frequently work with ICI. The surveys were distributed to a large pool of potential respondents, including 153 signal owner or operator contacts representing the vast majority of road authorities in the state, and 68 modelers including people in the public, private, and academic sectors. Ultimately 42 responses to the Owners and Operators survey, and 25 responses to the Modelers survey were received.

2.4.2 Information Obtained from Survey

The most significant information obtained from the surveys concerned the availability and formats of intersection control information. Table 2-2 enumerates all the formats in which each type of information may be contained, based on the responses to the survey distributed to organizations that own and operate traffic signals. Note that this is an attempt at a complete list, not an estimate of how common any particular format is, as all information would need to be digitized regardless of how common it is to keep it in a given format. As can be seen in the table, many agencies store all or most of the information about their intersections in a CTSCS, ATMS, or closed-loop system that is already digitized. While this is good, depending on the particular system used, what information fields it can store, and how it arranges that information, the method for storing certain pieces of information may vary between and within agencies. For instance, if comment fields were used to store information in a non-standard way, fitting this information into a standardized format would still require interpretation and manual effort.

Aside from central systems, a number of agencies also store their ICI in spreadsheets, PDF files, and paper records. Even in the case of spreadsheets, which are already digital, again the issue of how the data is organized means that interpretation would be required to translate these records into a standardized format. Some additional storage formats that were identified from the survey but had not occurred to researchers include using Autoscope machine vision sensor software to store detector-phase assignments, and using a generic asset management system or service to store information about signals (as opposed to a CTSCS or ATMS system specific to signal operation).

In addition to the survey of signal operators, researchers also surveyed designers, modelers, and planners that frequently work with ICI to learn what programs they use and what data they require as part of this. Since the project researchers are already highly experienced in this area not much new information was obtained, however the results helped to confirm what modeling programs are commonly used, what information they typically need, and some of the experiences modelers have when requesting signal data. There were also some suggestions for ways the process of importing signal data into their models could be improved, such as providing Synchro files or controller databases, which many programs already have tools to import. There were also suggestions that an online, interactive map would be convenient for accessing data. Further discussion of researchers' recommendations concerning how a system for managing this information could be implemented, taking into account the responses to the surveys, can be found in Chapter 3.

Table 2-2 Availability (by format) of intersection control information categories in jurisdictions around Minnesota.

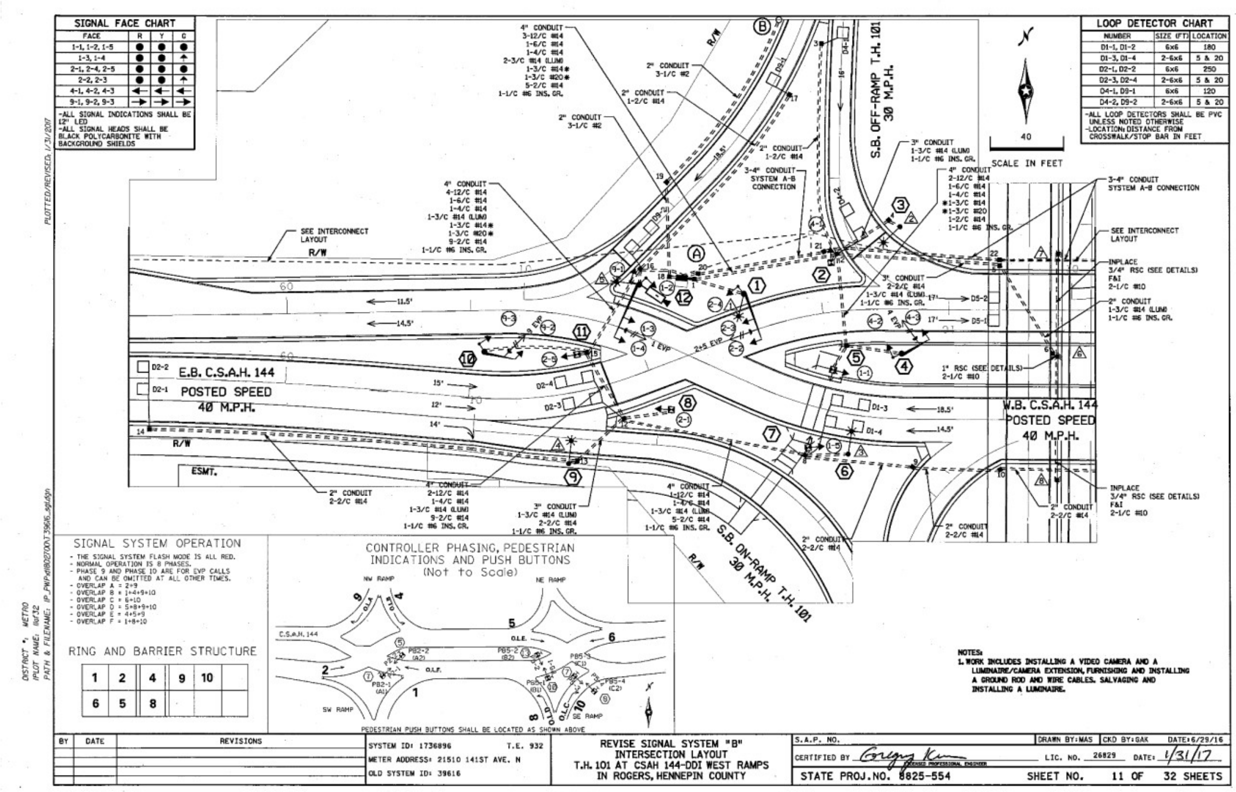
	Signal owner	Communication capabilities (i.e. network connection to the cabinet)	Date of last update to traffic control information	Geo-Locations	Detector-Phase Assignments	Program Schedule	Signal Timing Information	Active Signal Timing Info	TSP/EVP	Type of Coordination
Asset Management System/Service				√	√	√	√	√	√	√
Autoscope					√					
Cabinet Log (paper record located in cabinet)								√		
Central Traffic Signal Control Systems (e.g. MaxView)	√	√	√	√	√	√	√	√	√	√
Closed-Loop Traffic Control System (e.g. Aries)	√	√	√	√	√	√	√	√	√	√
Construction plans				√	√	√			√	√
Database Application	√	√	√							
GIS/Geodatabase	√	√	√	√						
Paper records	√	√	√	√	√	√	√	√	√	√
PDF files of digital documents	√	√	√	√	√	√	√	√	√	√
PDF files of scanned documents	√	√	√	√	√	√	√	√	√	√
Spreadsheets	√	√	√	√	√	√	√	√	√	√
Synchro 9, 10										√

CHAPTER 3: UNIFIED SET OF INTERSECTION CONTROL INFORMATION

3.1 METHODOLOGY

Researchers employed a multi-pronged approach when collecting information on the various aspects of intersection control, incorporating information from multiple sources in an effort to make the results of the process cover as many cases as possible. This included interviewing signal operators from multiple agencies to understand the systems they use, their data management practices, and how they respond to information requests, as well as their thoughts on how distribution of ICI could be improved. In addition to this, researchers developed two surveys, one distributed to signal owners and operators around the state requesting similar information about their practices and the systems they use, and another distributed to designers, modelers, and planners that frequently model signalized intersections to understand how they use this information and what data formats are most convenient for them. These surveys are presented in full in Appendices A and C, with the full results of the surveys presented in Appendices B and D.

Separately, researchers also reviewed information obtained from signal operators describing several example intersections from around the metro area. This effort focused on intersections with complicated designs, such as the Diverging Diamond Interchange (DDI) and intersections with more than four legs, to ensure that the resulting set of intersection control information would adequately capture these cases. To this end, researchers specifically made the point of creating a full example of the unified set of intersection control information for the DDI at Hennepin County Road 144 and TH-101 in Rogers, MN, the plan for which is shown in Figure 3.1, to ensure that the resulting unified set of ICI could represent this complex intersection. This full example can be found in Appendix E. Along with these, researchers reviewed manuals covering traffic engineering, signal operation best practices, and standards governing the operation of signal controllers to verify that the recommended set of ICI conforms to the typical practices and terminology of the industry. Researchers also drew upon personal experience working with transportation modeling and traffic simulation software to ensure that the resulting ICI set would support the majority of modeling activities.



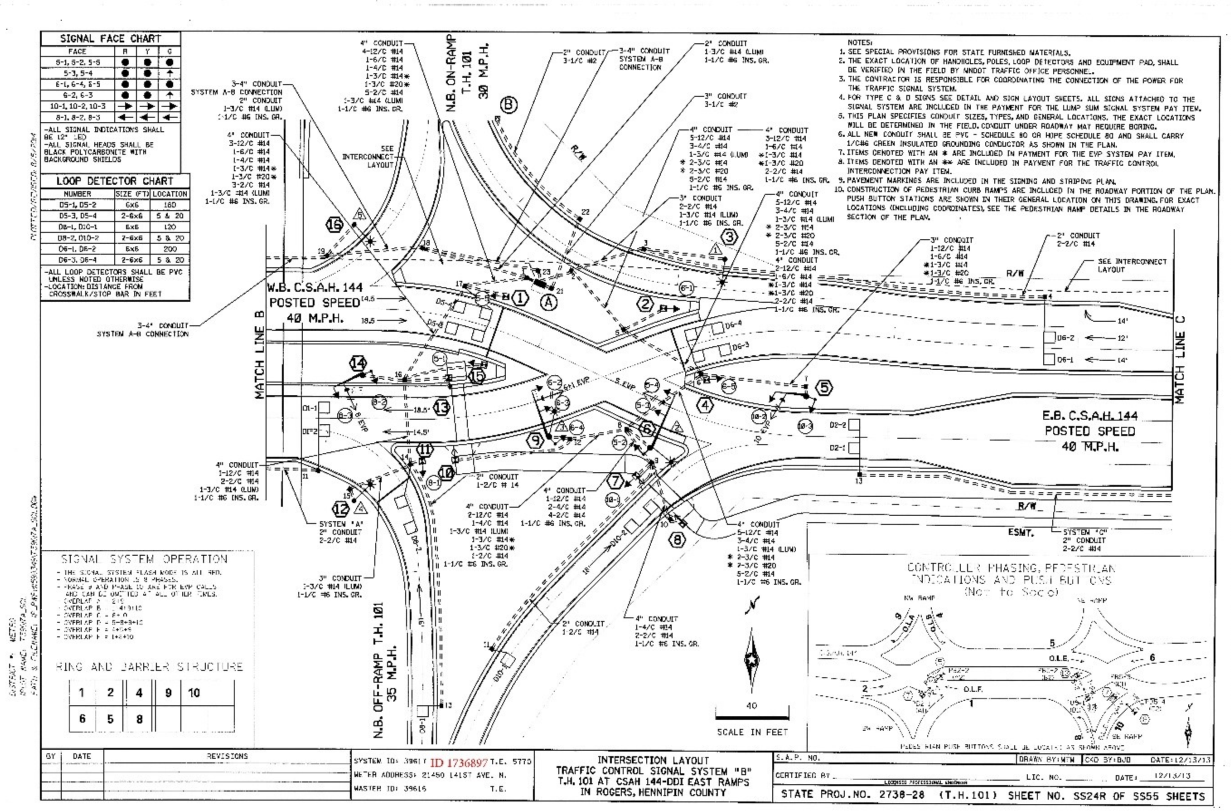


Figure 3.1 Plan documents for the Diverging Diamond Interchange at Hennepin County Road 144 and TH-101 in Rogers, MN, used when creating the unified set of ICI.

In the case of ICI relating specifically to program information, researchers based this primarily on the National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) 1202 standard, *Object Definitions for Actuated Traffic Signal Controller Units*, version 2, published in 2005. This standard already rigorously defines the information required to describe the control of an intersection as seen by a signal controller at a technical level, and many commercial software vendors are already very familiar with its contents. This also allows the unified set of ICI developed in this project to be kept updated as intersection control technology evolves to meet the needs of a changing transportation system. Along with this standard, researchers reviewed control information from example intersections and added, moved, or modified certain parameters to include important parameters that were missing, and to make the resulting set of ICI easier to follow.

3.2 UNIFIED SET OF INTERSECTION CONTROL INFORMATION (ICI)

The following tables contain the unified set of intersection control information as developed by researchers. Broadly, the information falls into three main groups: “high-level” information, such as the agency that owns the signal, the geographic location of the intersection, and the specific controller unit installed; geometric information, such as the approaches, lanes, and detector locations; and program information, such as schedules, plans, and phases. Program information is split over several tables that structure the information based on how each parameter affects the operation of the intersection, how it relates to other parameters, and how frequently it changes. The program information structure is highly influenced by the organization of information in NTCIP 1202, but includes several information-coding modifications to minimize entries unrelated to this project’s needs.

For the most part, information in the “high-level” table (Table 3-1) is not strictly relevant to the control of the intersection, however it contains key information describing the location of the intersection, the roads intersecting, the agency/agencies that own and operate the intersection, and the hardware and software used to control and administer the intersection. Some of this information is crucial to modeling an intersection, particularly the precise geographic location in an unambiguous format (latitude and longitude), while the remaining information provides context about the intersection that can be important for understanding other control information.

Geometric information, contained in Table 3-2, is meant to describe necessary physical attributes of the intersection and how they relate to the program information that is set on the controller. This information is structured around entrance approaches to the intersection. For each approach, there is information about the road name and the ROW authority, as well as the direction of travel, allowing intersections with more than four legs or with complicated layouts to be described accurately. Approaches are then broken down into lane groups, groups of lanes that are presented the same signal indication and are associated with a particular movement (e.g. left, right, thru, thru-left, etc.). Lane groups are also associated with a vehicle phase or overlap channel and a pedestrian phase channel that explain how the particular lane group is directed by the controller. In addition to this, the lane group also contains information describing the indicators on the face of the signal head, as well as other lane groups in other approaches that conflict with the given lane group. Pedestrian crossings that cross each lane group are also defined here. For each lane in the lane group, there is information describing the width of the lane, the detector(s) and their distance from the stop line, and the allowed turnings (destination lanes) that a vehicle may access from this lane.

Program information begins with channels, which connect a physical load switch in the cabinet that controls a signal head to a control source like a phase or overlap. Each channel is referenced in the geometric information of an approach, providing a flexible means for relating geometry with phasing. After channels, comes information describing vehicle detectors (Table 3-4) and pedestrian detectors/buttons (Table 3-5). These contain phase calling information and detector options, providing a link between the physical locations of the detectors and how they affect the control of the intersection. Fault information is also provided to explain how failures are handled.

While channels and detectors provide a means for linking the physical geometry of the intersection with the control information, everything after that consists of parameters and options that are set in the controller. These parameters determine how the controller operates across different dates and times, including how detection inputs are handled and how it affects the channel outputs. The parameters are structured to match the flexibility available in a typical actuated controller, where there are multiple ways to alter the controller function using parameter sets that are optimized for certain traffic patterns. At the highest level of this, there are a handful of global parameters (Table 3-6) that affect the operation of the controller and can only be set to one value. These include the default red revert time, options for what to do after powering up and how to handle automatic flash conditions, and the state of coordination.

Following this, there are a variable number of Static Phase Parameter Sets (Table 3-7) that control how an individual phase should be timed. Each of these includes values like minimum/maximum green times, pedestrian walk and clear interval times, yellow and red times, and gap reduction parameters, among others. Each one of these parameter sets can be applied to any number of actual phases (via Patterns), and are not otherwise associated with any particular phase.

Schedule information is defined in two tables. The first of these, Schedules (Table 3-8), describes how the control information should change based on the month, day or week, or date, allowing operators to adjust the operation for typical traffic, weekends, holidays, and so on. On each day, a matching Schedule will be selected and used to select a Day Plan (Table 3-9). Each Day Plan consists of a number of Events, where based on the current time a certain Pattern will be selected.

Patterns (Table 3-10) define the parameters of the controller that are in operation at any given time. This includes the cycle time, any offset time that is in effect for coordination, a few other options. The Pattern also points to a Split Pattern (Table 3-11) and Sequence (Table 3-12) that are in effect, and also denotes which set of Static Phase Parameters should be used for each individual phase. The Split Pattern describes, for each active phase, the total split time for that phase as well as any options for how that phase should operate, such as activity after startup or during automatic flash, detector lock memory, and vehicle and pedestrian recalls, among others. The Sequence describes the ring and barrier structure of the phases, along with the ordering of each phase on each ring.

Overlaps (Table 3-13) describe any phases that can overlap and how each Overlap is implemented. These can be assigned as a control source for channels as an alternate to individual phases, allowing movements that don't conflict with one another to operate at the same time. Protected/Permissive Left Turn Flashing Yellow Arrow (FYA) functionality (Table 3-14) can be applied to an Overlap by noting which phases correspond to the protected left turn phase and the permissive through phase. Finally, emergency vehicle or railroad preemption is defined in the Preempts table (Table 3-15), where each Preempt plan contains parameters that affect how a call interrupts normal operation, how long it should remain in effect, and how the controller returns to normal operation. To show the organization of this information, Figure 3.2 shows a high-level view of the tables with lines connecting the important fields to illustrate how the information in each table connects to related information in other tables.

Together, these structures can be used to represent all of the information that is relevant to the control of a signalized intersection and how that can change automatically over time. To demonstrate this, researchers filled in all values for the intersection of Hennepin County Road 144 and TH-101 in Rogers, MN, a DDI that controls access to and from the limited access freeway TH-101. Because of the complexity of this novel type of interchange, it can be difficult to describe them using models built around traditional four-leg intersections, making it a useful example case for ensuring that the unified set of ICI can adequately represent every intersection. The full set of information for this example can be found in Appendix E. In the tables in this section, each parameter is accompanied by a description and the units or data type used to represent the value.

The information required to assemble this unified set for a particular intersection will come mainly from one of three sources: the intersection controller, the construction plans showing the layout of the intersection and how it relates to the control of the intersection, or general GIS information such as that available from Google Maps or an agency's records. To illustrate this, Figure 3.3 shows a high-level view of each table and the typical sources for that information.

Table 3-1 Information describing the intersection at a high level.

Name	**Description**	**Data Type/Units**
Owner Agency	Agency that owns the signal	String
Operating Agency	Agency that operates the signal	String
Location (Latitude & Longitude)	Location of the intersection expressed in latitude & longitude coordinates	Decimal degrees
Corridor	Primary corridor of the intersection (especially for coordinated signals)	String
Major Road Name	Major road served by the intersection.	String
Major Road Owner	The agency that owns the major road.	String
Minor Road	Minor road served by the intersection.	String
Minor Road Owner	The agency that owns the minor road.	String
Cabinet Type	Type (standard) of controller cabinet	String
Installation Date	Date of cabinet and controller installation (most recent physical change)	Date
Communication Type	Connection to a network and technology used	String
Management System	Management system used to administer the signal	String
Date/Time of Last Traffic Control Info Update	Date and time of last update of traffic control information	Date and time
Controller Type (standard)	Type (standard) of signal controller (highest/most recent)	String
Controller Manufacturer	Manufacturer of the signal controller	String
Controller Model	Model of the signal controller	String

Table 3-2 Information describing the geometry of the intersection and how it relates to program information.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Sub-Level 3 Name	Sub-Level 4 Name	Description	Data Type/Units
Number of Approaches					Number of approaches entering the intersection (identified by signal masts)	Integer Quantity
(per Approach):					Information describing each Approach	
	Approach Index				ID of this Approach	Index
	Approach Name				Name of the approach	String
	Owner				Agency that owns this approach	String
	Azimuth (Direction of Travel)				Direction of travel for this approach expressed as azimuth	Decimal Degrees
	Number of Lanes				Number of total lanes for this approach (all lane groups)	Integer Quantity
	Bicycle Lane				Presence of a bicycle lane	Boolean
	Bicycle Detection/Button				Presence of bicycle detection/button	Boolean
	Number of Lane Groups				Number of lane groups, i.e. one or more lanes shown the same control indicator (see "Lane Group N" below)	Integer Quantity
	(per Lane Group):				Information describing each Lane Group	
		Lane Group Index			ID of this Lane Group	Index
		Movement Type			Movement type of this lane group	String
		Protected/Permissive			Whether this lane group has a protected phase, permissive phase, or both	String
		Turn on Red			Whether or not this lane group may turn on red	Boolean

		Vehicle Phase/Overlap Channel			The ID of the Channel that controls the vehicle phase or overlap for this lane group.	Integer Channel #
		Pedestrian Phase Channel			The ID of the Channel that controls the pedestrian phase this lane group.	Integer Channel #
		Signal Face			Signal face indications for this lane group (ball, left arrow, right arrow)	
			Red		Red signal face indicator	String
			Yellow		Yellow signal face indicator	String
			Flashing Yellow Arrow		Flashing yellow signal face indicator	String
			Green		Green signal face indicator	String
		Number of Conflicting Lane Groups			Number of other lane groups that conflict with this lane group	Integer Quantity
		(per conflicting lane group):			Information describing each Conflicting Lane Group	
			Conflicting Lane Group N Index		ID of a Lane Group that conflicts with this lane group	Index
		Pedestrian Crossing			Whether or not there is a pedestrian crosswalk for crossing this lane group	Boolean
		Pedestrian Crosswalk Width			Width of the crosswalk for crossing this lane group	Feet
		Pedestrian Button/Detection			Presence of a pedestrian button or other detection	Boolean
		Number of Lanes			Number of lanes in this lane group	Integer Qty.
		(per lane):			Information describing each Lane	
			Lane Index		ID of this Lane (starting from the right)	Index

			Width		Width of the lane measured at the stop line of the intersections (in feet).	Feet
			Number of Detectors		Number of detectors in this lane	Integer Quantity
			(per detector):		Information describing each Detector	
				Detector Index	ID of this Detector	Index
				Detector Type	Type of detector	String
				Distance from Stop Line	Distance of the detector from the stop line of the intersection	Feet
			Number of Turnings		Number of turnings (allowed destination lanes) from this lane	Integer Quantity
			(per turning):		Information describing each Turning	
				Turning Index	ID of this Turning	Index
				Destination Approach and Lane	Destination approach and lane for this turning	Index

Table 3-3 Information describing the output Channels of the signal controller.

Name	Sub-Level 1 Name	Description	Data Type/Units
Number of Channels		Number of output channels/load switches supported by this controller	Integer Quantity
(per Channel):		Information describing each Channel	
	Channel Index	ID of this Channel	Index
	Control Source	Control source of this Channel (vehicle or pedestrian phase, overlap, or other, and ID of the source)	Index

Table 3-4 Information describing the detector parameters at an intersection.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Description	Data Type/Units
Number of Vehicle Detectors			Number of Vehicle Detectors (physical or virtual) at the intersection	Integer Quantity
(per Vehicle Detector):			Information describing each Vehicle Detector	
	Vehicle Detector Index		ID of this Vehicle Detector	Index
	Vehicle Detector Geometric Index		ID of this Vehicle Detector in the intersection's geometric information (gives detector location)	Index
	Primary Call Phase Index		ID of the primary vehicle phase called by this Vehicle Detector	Index
	Number of Secondary Phases Called		Number of secondary vehicle phases called by this Vehicle Detector	Integer Quantity
	(per Secondary Called Phase):		Information describing each secondary vehicle phase called by this Vehicle Detector	
		Secondary Call Phase Index	ID of a secondary vehicle phase called by this Vehicle Detector	Index

	Volume Detector		Whether or not this detector collects volume data	Boolean
	Occupancy Detector		Whether or not this detector collects occupancy data	Boolean
	Yellow/Red Lock Call		If enabled, the detector will lock a call to the to the primary call phase if an actuation occurs while the phase is not timing Green (Yellow Lock) or while it is not timing Green or Yellow (Red Lock) (NTCIP 1202:2005 v02.19, 33).	String
	Passage		"[I]f Enabled, the CU shall maintain a reset to the associated phase passage timer for the duration of the detector actuation when the phase is green" (NTCIP 1202:2005 v02.19, 33).	Boolean
	Added Initial		"[I]f Enabled, the CU shall accumulate detector actuation counts for use in the added initial calculations. Counts shall be accumulated from the beginning of the yellow interval to the beginning of the green interval" (NTCIP 1202:2005 v02.19, 33).	Boolean
	Queue		"[I]f Enabled, the CU shall extend the green interval of the assigned phase until a gap occurs (no actuation) or until the green has been active longer than the vehicleDetectorQueueLimit time" (NTCIP 1202:2005 v02.19, 33).	Boolean
	Call		"[I]f Enabled, the CU shall place a demand for vehicular service on the assigned phase when the phase is not timing the green interval and an actuation is present" (NTCIP 1202:2005 v02.19, 33).	Boolean
	Switch Phase Index		"The phase to which a vehicle detector actuation shall be switched when the assigned phase is Yellow or Red and the Switch Phase is Green" (NTCIP 1202:2005 v02.19, 34).	Index
	Delay		"The period a detector actuation (input recognition) shall be delayed when the phase is not Green" (NTCIP 1202:2005 v02.19, 34).	Seconds
	Extend		"The period a vehicle detector actuation (input duration) shall be extended from the point of termination , when the phase is Green" (NTCIP 1202:2005 v02.19, 35).	Seconds
	Queue Limit		"The length of time that an actuation from a queue detector may continue into the phase green. This time begins when the phase becomes green and when it expires any associated detector inputs shall be ignored. This time may be shorter due to other overriding device parameters" (NTCIP 1202:2005 v02.19, 35).	Seconds
	No Activity		"If an active detector does not exhibit an actuation in the specified period, it is considered a fault by the diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for this detector" (NTCIP 1202:2005 v02.19, 35).	Minutes

	Max Presence		"If an active detector exhibits continuous detection for too long a period, it is considered a fault by the diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for this detector" (NTCIP 1202:2005 v02.19, 36).	Minutes
	Erratic Counts		"If an active detector exhibits excessive actuations, it is considered a fault by the diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for this detector" (NTCIP 1202:2005 v02.19, 36).	Integer Count
	Fail Time		"If a detector diagnostic indicates that the associated detector input is failed, then a call shall be placed on the associated phase during all non-green intervals. When each green interval begins the call shall be maintained for the length of time specified by this object and then removed" (NTCIP 1202:2005 v02.19, 36-37).	Seconds
	No Activity Fault		"This detector has been flagged as non-operational due to lower than expected activity by the CU detector diagnostic" (NTCIP 1202:2005 v02.19, 37).	Boolean
	Max Presence Fault		"This detector has been flagged as non-operational due to a presence indicator that exceeded the maximum expected time by the CU detector diagnostic" (NTCIP 1202:2005 v02.19, 37).	Boolean
	Erratic Output Fault		"This detector has been flagged as non-operational due to erratic outputs (excessive counts) by the CU detector diagnostic" (NTCIP 1202:2005 v02.19, 37).	Boolean
	Communications Fault		"Communications to the device (if present) have failed" (NTCIP 1202:2005 v02.19, 37).	Boolean
	Configuration Fault		"Detector is assigned but is not supported" (NTCIP 1202:2005 v02.19, 37).	Boolean
	Other Fault		"The detector has failed due to some other cause" (NTCIP 1202:2005 v02.19, 37).	Boolean
	Other Reported Fault		"This detector has been flagged as non-operational due to some other error" (NTCIP 1202:2005 v02.19, 38).	Boolean
	Watchdog Fault		"This detector has been flagged as non-operational due to a watchdog error" (NTCIP 1202:2005 v02.19, 38).	Boolean
	Open Loop Fault		"This detector has been flagged as non-operational due to an open loop (broken wire)" (NTCIP 1202:2005 v02.19, 38).	Boolean
	Shorted Loop Fault		"This detector has been flagged as non-operational due to a shorted loop wire" (NTCIP 1202:2005 v02.19, 38).	Boolean
	Excessive Change Fault		"This detector has been flagged as non-operational due to an inductance change that exceeded expected values" (NTCIP 1202:2005 v02.19, 38).	Boolean

Table 3-5 Information describing the pedestrian detectors/buttons at an intersection.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Description	Data Type/Units
Number of Pedestrian Detectors			Number of Pedestrian Detectors/Buttons at the intersection	Integer Quantity
(per Pedestrian Detector):			Information describing each Pedestrian Detector	
	Pedestrian Detector Index		ID of this Pedestrian Detector	Index
	Primary Call Phase Index		ID of the phase called by this Pedestrian Detector	Index
	Number of Secondary Phases Called		Number of secondary phases called by this Pedestrian Detector	Integer Quantity
	No Activity		"If an active detector does not exhibit an actuation in the specified period, it is considered a fault by the diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for this detector" (NTCIP 1202:2005 v02.19, 45).	Minutes
	Max Presence		"If an active detector exhibits continuous detection for too long a period, it is considered a fault by the diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for this detector" (NTCIP 1202:2005 v02.19, 46).	Minutes
	Erratic Counts		"If an active detector exhibits excessive actuations, it is considered a fault by the diagnostics and the detector is classified as Failed. A value of 0 for this object shall disable this diagnostic for this detector" (NTCIP 1202:2005 v02.19, 46).	Integer Count
	No Activity Fault		"This detector has been flagged as non-operational due to lower than expected activity by the CU detector diagnostic" (NTCIP 1202:2005 v02.19, 47).	Boolean
	Max Presence Fault		"This detector has been flagged as non-operational due to a presence indicator that exceeded the maximum expected time by the CU detector diagnostic" (NTCIP 1202:2005 v02.19, 47).	Boolean
	Erratic Output Fault		"This detector has been flagged as non-operational due to erratic outputs (excessive counts) by the CU detector diagnostic" (NTCIP 1202:2005 v02.19, 47).	Boolean

	Communications Fault		"Communications to the device (if present) have failed" (NTCIP 1202:2005 v02.19, 47).	Boolean
	Configuration Fault		"Detector is assigned but is not supported" (NTCIP 1202:2005 v02.19, 46-47).	Boolean
	Other Fault		"The detector has failed due to some other cause" (NTCIP 1202:2005 v02.19, 46).	Boolean

Table 3-6 Information describing global parameters of the signal controller.

<u>Name</u>	<u>Description</u>	<u>Data Type/Units</u>
Start Up Flash	Amount of time during which all phases are in flash after power start	Seconds
All Red	Amount of time during which all phases are red after a flash condition ends	Seconds
Power Start Sequence Index	ID of the Sequence that is used at start up (overridden by Schedule information)	Index
Minimum Flash	Amount of time that the controller must remain in flash before it may exit	Seconds
Pedestrian Clearance Protection	Whether or not to enable Pedestrian Clearance Protection when manual control is enabled	Boolean
Red Revert	Minimum Red indication to be timed after a Yellow Change interval before any phase can display Green again	Seconds
Coordinated Operational Mode	Operational mode for Coordination (Automatic, Manual Pattern, Manual Free, Manual Flash) (NTCIP 1202:2005 v02.19, 57).	String
Coordinated Correction Mode	Coordination correction mode (Add Only, Shortway, Dwell, Other) (NTCIP 1202:2005 v02.19, 57-58).	String
Coordinated Maximum Mode	Maximum timing in effect during coordination (Max Inhibit, Maximum 1, Maximum 2, Other) (NTCIP 1202:2005 v02.19, 58).	String
Coordinated Force Mode	Pattern Force Mode in effect during coordination (Fixed, Floating, Other) (NTCIP 1202:2005 v02.19, 58-59).	String

Table 3-7 Information describing a set of phase parameters that may be used for one or more phases by a controller.

Name	Sub-Level 1 Name	Description	Data Type/Units
Number of Phase Parameter Sets		Number of parameter sets containing static phase parameters for a controller.	Integer Quantity
(per Phase Parameter Set):		Information describing each Phase Parameter Set, containing control parameters that can be applied to an actual phase	
	Phase Parameter Set Index	ID of this Phase Parameter Set	Index
	Walk	Phase Walk Parameter in seconds, controlling the amount of time the Walk indication shall be displayed (NTCIP 1202:2005 v02.19, 10).	Seconds
	Pedestrian Clear	Phase Pedestrian Clear parameter in seconds, controlling the duration of the Pedestrian Clearance output and the flashing period of the Don't Walk output (NTCIP 1202:2005 v02.19, 11).	Seconds
	Minimum Green	"Phase Minimum Green Parameter in seconds (NEMA TS 2 range: 1-255 sec). The first timed portion of the Green interval which may be set in consideration of the storage of vehicles between the zone of detection for the approach vehicle detector(s) and the stop line" (NTCIP 1202:2005 v02.19, 11).	Seconds
	Bike Minimum Green	The minimum green time in seconds due to a bike detector call (Econolite, 7-3).	Seconds
	Passage	"When minimum green finishes timing, the green interval is allowed to extend for a length of time equal to maximum time in effect. Actual length of extension period depends on this phase vehicle extension time, frequency of vehicle actuations and minimum gap setting" (Econolite, 7-5).	Seconds
	Maximum 1	Maximum green time in seconds this phase may be held in presence of a conflicting call. Can be overridden via an external input or other method (NTCIP 1202:2005 v02.19, 12).	Seconds
	Maximum 2	Maximum green time in seconds this phase may be held in presence of a conflicting call implemented via an external input or other method (NTCIP 1202:2005 v02.19, 12).	Seconds
	Yellow Change	Duration of the yellow change interval in seconds for the phase	Seconds
	Red Clear	Duration of the red clearance interval in seconds for the phase	Seconds

	Red Revert	"Red revert time parameter [in seconds]. A minimum Red indication to be timed following the Yellow Change interval and prior to the next display of Green on the same signal output driver group" (NTCIP 1202:2005 v02.19, 13).	Seconds
	Added Initial	"Phase Added Initial Parameter [in seconds]... Added Initial parameter (Seconds / Actuation) shall determine the time by which the variable initial time period will be increased from zero with each vehicle actuation received during the associated phase Yellow and Red intervals" (NTCIP 1202:2005 v02.19, 14).	Seconds
	Maximum Initial	"The maximum value of the variable initial timing period... The variable initial time shall not be less than Minimum Green" (NTCIP 1202:2005 v02.19, 14).	Seconds
	Time Before Reduction	"Phase Time Before Reduction (TBR) Parameter in seconds... The Time Before Reduction period shall begin when the phase is Green and there is a serviceable conflicting call. If the serviceable conflicting call is removed before completion of this time (or time to reduce), the timer shall reset. Upon completion of the TBR period or the CarsBeforeReduction (CBR) parameter is satisfied, whichever occurs first, the linear reduction of the allowable gap from the Passage Time shall begin" (NTCIP 1202:2005 v02.19, 14-15).	Seconds
	Cars Before Reduction	"Phase Cars Before Reduction (CBR) Parameter... When the phase is Green and the sum of the cars waiting (vehicle actuations during Yellow & Red intervals) on serviceable conflicting phases equals or exceeds the CBR parameter or the Time Before Reduction (TBR) parameter is satisfied, whichever occurs first, the linear reduction of the allowable gap from the Passage Time shall begin" (NTCIP 1202:2005 v02.19, 15).	Integer Count
	Time To Reduce	"Phase Time To Reduce Parameter in seconds... This parameter shall control the rate of reduction of the allowable gap between the Passage Time and Minimum Gap setting" (NTCIP 1202:2005 v02.19,15).	Seconds
	Reduce By	"This object may be used for volume density gap reduction as an alternate to the linear reduction defined by NEMA TS 1 and TS 2. It contains the…seconds to reduce the gap by... The frequency of reduction shall produce the Minimum Gap after a time equal to the 'phaseTimeToReduce' object" (NTCIP 1202:2005 v02.19, 16).	Seconds
	Minimum Gap	"Phase Minimum Gap Parameter [in seconds]... The reduction of the allowable gap shall continue until the gap reaches a value equal to or less than the minimum gap as set on the Minimum Gap control after which the allowable gap shall remain fixed at the values set on the Minimum Gap control" (NTCIP 1202:2005 v02.19, 16).	Seconds
	Dynamic Max Limit	"This object shall determine either the upper or lower limit of the running max in seconds...during dynamic max operation" (NTCIP 1202:2005 v02.19, 16-17).	Seconds
	Dynamic Max Step	"This object shall determine the automatic adjustment to the running max [in seconds]" (NTCIP 1202:2005 v02.19, 17).	Seconds

Table 3-8 Information describing the month/day/date program schedule for the signal controller.

Name	Sub-Level 1 Name	Description	Data Type/Units
Number of Schedules		Number of Schedules used to set the program running on the controller based on month, day of week, and date	Integer Quantity
Schedule *N*		Information describing Schedule *N*	
(per Schedule):	Month	Month numbers (1 for January - 12 for December) during which the corresponding Day Plan is active	List of Integers
	Day of Week	Day of week numbers (1 for Sunday - 7 for Saturday) during which the corresponding Day Plan is active	List of Integers
	Date	Day of month numbers (1 - 31) during which the corresponding Day Plan is active	List of Integers
	Day Plan Index	Index of the Day Plan that should operate on the corresponding day(s)	Index

Table 3-9 Information describing the time of day program schedule for the signal controller.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Description	Data Type/Units
Number of Day Plans			Number of Day Plans used to set the control information used by the controller based on time of day.	Integer Quantity
Day Plan *N*			Information Describing Day Plan *N*	
(per Day Plan):	Number of Events		Number of Events during which the control information changes in response to time of day	Integer Quantity
	Event *N*		Information describing Event *N*	
	(per Event):	Start Hour	Beginning hour (0-23) at which the corresponding Action should be run.	Integer
		Start Minute	Beginning minute (0-59) at which the corresponding Action should be run.	Integer
		Pattern Index	Index of the Pattern that should run at this time.	Index

Table 3-10 Information describing a particular Pattern containing phasing information for a controller.

Name	Sub-Level 1 Name	Description	Data Type/Units
Number of Patterns		Number of Patterns describing the parameters for a specific controller pattern.	Integer Quantity
Pattern *N*		Information describing Pattern *N*	
(per Pattern):	Cycle Time	Length of the cycle for this pattern in seconds	Seconds
	Offset Time	The number of seconds that the local time zero shall lag the system time zero for this pattern to allow coordination (NTCIP 1202, 62)	Seconds
	Split Pattern Index	Index of the Split Pattern that should be used along with this Pattern	Index
	Sequence Index	Index of the Sequence that should be used along with this Pattern	Index
	Actuated Coordinated	Whether or not this Pattern is a coordinated pattern	Boolean
	Actuated Walk Rest	Whether or not non-actuated phases should remain in the timed-out Walk state in absence of a conflicting call (NTCIP 1202, 53)	Boolean
	Enable FYA	Whether or not to enable Protected/Permissive Flashing Yellow Arrow functionality for this pattern (only applies if FYA Overlaps are defined)	Boolean
	Phase 1 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 1 of this pattern.	Index
	Phase 2 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 2 of this pattern.	Index
	Phase 3 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 3 of this pattern.	Index
	Phase 4 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 4 of this pattern.	Index
	Phase 5 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 5 of this pattern.	Index
	Phase 6 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 6 of this pattern.	Index
	Phase 7 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 7 of this pattern.	Index
	Phase 8 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 8 of this pattern.	Index
	Phase 9 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 9 of this pattern.	Index
	Phase 10 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 10 of this pattern.	Index

	Phase 11 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 11 of this pattern.	Index
	Phase 12 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 12 of this pattern.	Index
	Phase 13 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 13 of this pattern.	Index
	Phase 14 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 14 of this pattern.	Index
	Phase 15 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 15 of this pattern.	Index
	Phase 16 Parameter Set	Index of the Phase Parameter Set that should be used for Phase 16 of this pattern.	Index

Table 3-11 Information describing a particular Split Pattern containing information about phase splits for a controller.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Description	Data Type/Units
Number of Split Patterns			Number of coordination split parameters (Split Patterns) in this controller	Integer Quantity
(per Split Pattern):			Information describing each Split Pattern	
	Split Pattern Index		ID of this Split Pattern	Index
	Number of Phases		Number of Phases described in this Split Pattern	Integer Quantity
	(per Phase):		Information describing each Phase in this Split Pattern	
		Phase Index	ID of this Phase in this Split Pattern	Index
		Split Time	"The time in seconds the splitPhase is allowed to receive (i.e. before a Force Off is applied) when constant demands exist on all phases. In floating coordForceMode, this is always the maximum time a non-coordinated phase is allowed to receive. In fixed coordForceMode, the actual allowed time may be longer if a previous phase gapped out" (NTCIP 1202:2005 v02.19, 64).	Seconds
		Coordinated Phase	Whether or not this phase is a coordinated phase.	Boolean

		Startup	"The Phase Startup parameter is an enumerated integer which selects the startup state for each phase after restoration of a defined power interruption or activation of the external start input." Defined modes are: Other (1), Phase Not On (2), Green Walk (3), Green No Walk (4), Yellow Change (5), Red Clear (6) (NTCIP 1202:2005 v02.19, 18).	String
		Automatic Flash Entry Phase	"When Automatic Flash is called, the CU shall service the Entry Phase(s), clear to an All Red, then initiate flashing operation" (NTCIP 1202:2005 v02.19, 20).	Boolean
		Automatic Flash Exit Phase	"The CU shall move immediately to the beginning of the phase(s) programmed as Exit Phase(s) when Automatic Flash terminates." (NTCIP 1202:2005 v02.19, 20).	Boolean
		Dual Entry Phase	When active in a multi-ring configuration "causes the phase to become active upon entry into a concurrency group (crossing a barrier) when no calls exist in its ring within its concurrency group" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Non-Actuated 1	"[C]auses a phase to respond to the Call To Non-Actuated 1 input (if present) or other method" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Non-Actuated 2	"[C]auses a phase to respond to the Call To Non-Actuated 2 input (if present) or other method" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Non Lock Detector Memory	When inactive, the call will be locked at the beginning of the yellow interval. When active, locking will depend on the active detector options (NTCIP 1202:2005 v02.19, 19).	Boolean
		Minimum Vehicle Recall	"[C]auses recurring demand for vehicle service on the phase when that phase is not in its Green interval" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Maximum Vehicle Recall	"[C]auses a call on a phase such that the timing of the Green interval for that phase shall be extended to Maximum Green time" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Pedestrian Recall	"[C]auses a recurring pedestrian demand which shall function in the same manner as an external pedestrian call except that it shall not recycle the pedestrian service until a conflicting phase is serviced" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Soft Vehicle Recall	"[C]auses a call on a phase when all conflicting phases are in green dwell or red dwell and there are no serviceable conflicting calls" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Simultaneous Gap Disable	When active in a multi-ring configuration, "disables a gapped out phase from reverting to the extensible portion" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Guaranteed Passage	"[E]nables an actuated phase operating in volume density mode (using gap reduction) to retain the right of way for the unexpired portion of the Passage time following the decision to terminate the green due to a reduced gap" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Actuated Rest In Walk	"[C]auses an actuated phase to rest in Walk when there is no serviceable conflicting call at the end of Walk Timing." (NTCIP 1202:2005 v02.19, 19).	Boolean

		Conditional Service Enable	When active in a multi-ring configuration, "causes a gapped/maxed phase to conditionally service a preceding actuated vehicle phase when sufficient time remains before max time out of the phase(s) not prepared to terminate" (NTCIP 1202:2005 v02.19, 19).	Boolean
		Added Initial Calculation	When active, "the CU shall compare counts from all associated AddedInitial detectors and use the largest count value for the calculations." When inactive, "the CU shall sum all associated AddedInitial detector counts and use this sum for the calculations" (NTCIP 1202:2005 v02.19, 18).	Boolean
		Phase Omitted	Whether or not this phase is omitted.	Boolean

Table 3-12 Information describing a particular Sequence containing phase order, ring, and barrier information for a controller.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Sub-Level 3 Name	Description	Data Type/Units
Number of Sequences				Number of Sequence plans in the controller, controlling ring and phase order information	Integer Quantity
(per Sequences):				Information describing each Sequence	
	Sequence Index			ID of this Sequence	Index
	Number of Rings			Number of Rings in this Sequence	Integer Quantity
	(per Ring):			Information describing each Ring in this Sequence	
		Ring Index		ID of this Ring in this Sequence	Index
		Number of Barriers		Number of Barriers in this Ring	Integer Quantity
		(per Barrier):		Information describing each Barrier	
			Barrier N Slot	Position of the second Barrier in this Ring (placed after this Slot number)	Index
		Number of Slots		Number of phase slots in this Ring	Integer Quantity
		(per Slot):		Information describing each Phase in this Ring	
			Slot 1 Phase	ID of the Phase that appears first in this Ring	Index

			Slot 2 Phase	ID of the Phase that appears second in this Ring	Index
			Slot 3 Phase	ID of the Phase that appears third in this Ring	Index
			Slot 4 Phase	ID of the Phase that appears fourth in this Ring	Index
			Slot 5 Phase	ID of the Phase that appears fifth in this Ring	Index

Table 3-13 Information describing a particular Overlap, describing overlapping phases for a controller.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Description	Data Type/Units
Number of Overlaps			Number of vehicle Overlaps	Integer Quantity
(per Overlap):			Information describing each Overlap	
	Overlap Index		ID of this Overlap	Index
	Overlap Type		Overlap type as defined in NTCIP 1202:2005 v02.19 Section 2.10.2.2 (101)	String
	Number of Included Phases		Number of phases included in this Overlap	Integer Quantity
	(per Included Phase):		Information describing each Phase included in this Overlap	
		Included Phase Index	Number of an included phase	Index
	Number of Modifier Phases		Number of modifier phases included in this Overlap (only applies to Overlap Type Minus Green Yellow) (NTCIP 1202:2005 v02.19, 102)	Integer Quantity
	Trailing Green		Amount of time to extend the overlap green after it would normally terminate (NTCIP 1202:2005 v02.19, 102)	Seconds
	Trailing Yellow Change		Duration of the yellow change interval for this Overlap when the Overlap green has been extended by Trailing Green (NTCIP 1202:2005 v02.19, 103)	Seconds
	Trailing Red Clear		Duration of the red clear interval for this Overlap when the Overlap green has been extended by Trailing Green (NTCIP 1202:2005 v02.19, 103)	Seconds

Table 3-14 Format of information describing Protected/Permissive Left Turn Flashing Yellow Arrow Overlaps for a controller.

Name	Sub-Level 1 Name	Description	Data Type/Units
Number of FYA Overlaps		Number of Protected/Permissive Left Turn Flashing Yellow Arrow Overlap Configurations	Integer Quantity
(per FYA Overlap):		Information describing each FYA overlap	
	Overlap Index	ID of the Overlap to which this FYA configuration applies	Index
	Protected Phase Index	ID of the Vehicle Phase corresponding to the Protected Left Turn movement (0 disables)	Index
	Permissive Phase Index	ID of the Vehicle Phase corresponding to the opposing Permissive Thru movement (0 disables)	Index
	FYA Delay Start	Amount of time to delay the flashing yellow arrow output after the beginning of the opposing Permissive Thru movement	Seconds

Table 3-15 Information describing a particular Preempt, describing emergency vehicle and/or railroad preemption functionality for a controller.

Name	Sub-Level 1 Name	Sub-Level 2 Name	Description	Data Type/Units
Number of Preempts			Number of Preempt plans in this controller	Integer Quantity
(per Preempt):			Information describing each Preempt	
	Preempt Index		ID of this Preempt	Index
	Non-Locking Memory		If enabled, do NOT execute a Preempt sequence if the Preempt input terminates before the delay time expires (NTCIP 1202:2005 v02.19, 75).	Boolean
	Preempt Override Flash		If enabled, automatic flash will NOT be overridden by this Preempt (NTCIP 1202:2005 v02.19, 75).	Boolean
	Preempt Override Number + 1		If enabled, this Preempt will NOT override the next higher numbered Preempt (NTCIP 1202:2005 v02.19, 75).	Boolean
	Flash Dwell		If enabled, Dwell Phases shall flash Yellow during the Dwell interval, and all other phases shall flash Red (NTCIP 1202:2005 v02.19, 75).	Boolean
	Link		ID of a higher-numbered Preempt that shall be called automatically following the end of the Dwell Green of this Preempt (NTCIP 1202:2005 v02.19, 75).	Index

	Delay		Amount of time (in seconds) to wait between receiving a call for this Preempt and executing it (NTCIP 1202:2005 v02.19, 76).	Seconds
	Minimum Duration		Minimum duration (in seconds) of this Preempt (NTCIP 1202:2005 v02.19, 76).	Seconds
	Minimum Green		Minimum duration of an existing Green on another phase that is terminated by this Preempt (NTCIP 1202:2005, v02.19, 76).	Seconds
	Minimum Walk		Minimum duration of an existing Walk on another phase that is terminated this Preempt (NTCIP 1202:2005 v02.19, 77).	Seconds
	Enter Pedestrian Clear		Duration of the Pedestrian Clear interval for a Walk signal on another phase terminated by this Preempt (NTCIP 1202:2005 v02.19, 77).	Seconds
	Track Green		Duration of the Track Clearance Green interval for this Preempt (NTCIP 1202:2005 v02.19, 77-78).	Seconds
	Minimum Dwell		Minimum duration of the Dwell interval phases for this Preempt (NTCIP 1202:2005 v02.19, 78).	Seconds
	Maximum Presence		Maximum time which this Preempt may remain active and be considered valid, after which normal operation is resumed (NTCIP 1202:2005 v02.19, 78).	Seconds
	Number of Track Phases		Number of phases that should be active during the Track Clear interval of this Preempt (NTCIP 1202:2005 v02.19, 79).	Integer Quantity
	(per Track Phase)		Information describing each Track Phase	
		Track Phase Index	ID of a phase to be active during the Track interval of this Preempt	Index
	Number of Dwell Phases		Number of vehicle phases that should be active during the Dwell interval of this Preempt (NTCIP 1202:2005 v02.19, 79).	Integer Quantity
	(per Dwell Phase):		Information describing each Dwell Phase	
		Dwell Phase Index	ID of a phase to be active during the Dwell interval of this Preempt	Index
	Number of Dwell Pedestrian Phases		Number of pedestrian phases that should be active during the Dwell interval of this Preempt (NTCIP 1202:2005 v02.19, 79-80).	0
	(per Dwell Pedestrian Phase)		Information describing each Dwell Pedestrian Phase	
		Dwell Pedestrian Phase Index	ID of a phase to be active during the Dwell Pedestrian interval of this Preempt	Index

	Number of Exit Phases		Number of phases that should be active following this Preempt (NTCIP 1202:2005 v02.19, 80).	0
	(per Exit Phase)		Information describing each Exit Phase	
		Exit Phase Index	ID of a phase to be active following this Preempt	Index
	Number of Track Overlaps		Number of overlaps that should be active during the Track Clear interval of this Preempt (NTCIP 1202:2005 v02.19, 81).	0
	(per Track Overlap)		Information describing each Track Overlap	
		Track Overlap Index	ID of an overlap to be active during the Track interval of this Preempt	Index
	Number of Dwell Overlaps		Number of overlaps that should be active during the Dwell interval of this Preempt (NTCIP 1202:2005 v02.19, 81).	1
	(per Dwell Overlap):		Information describing each Dwell Overlap	
		Dwell Overlap Index	ID of an overlap to be active during the Dwell interval of this Preempt	6
	Number of Cycling Phases		Number of vehicle phases allowed to cycle during the Preempt Dwell interval (NTCIP 1202:2005 v02.19, 81).	0
	(per Cycling Phase)		Information describing each Cycling Phase	
		Cycling Phase Index	ID of a vehicle phase allowed to cycle during the Dwell interval of this Preempt	Index
	Number of Cycling Pedestrian Phases		Number of pedestrian phases allowed to cycle during the Preempt Dwell interval (NTCIP 1202:2005 v02.19, 82).	0
	(per Track Phase)		Information describing each Cycling Pedestrian Phase	
		Cycling Pedestrian Phase Index	ID of a pedestrian phase allowed to cycle during the Dwell interval of this Preempt	Index
	Number of Cycling Overlaps		Number of overlaps allowed to cycle during the Preempt Dwell interval (NTCIP 1202:2005 v02.19, 82).	0
	(per Cycling Overlap)		Information describing each Cycling Overlap	
		Cycling Overlap Index	ID of an overlap allowed to cycle during the Dwell interval of this Preempt	Index

	Enter Yellow Change		Duration of the Yellow Change interval for a phase terminated by this Preempt (NTCIP 1202:2005 v02.19, 82).	Seconds
	Enter Red Clear		Duration of the Red Clear interval for a phase terminated by this Preempt (NTCIP 1202:2005 v02.19, 83).	Seconds
	Track Yellow Change		Duration of the Yellow Change interval of the Track Clearance movement of this Preempt (NTCIP 1202:2005 v02.19, 83).	Seconds
	Track Red Clear		Duration of the Red Clear interval of the Track Clearance movement of this Preempt (NTCIP 1202:2005 v02.19, 83).	Seconds

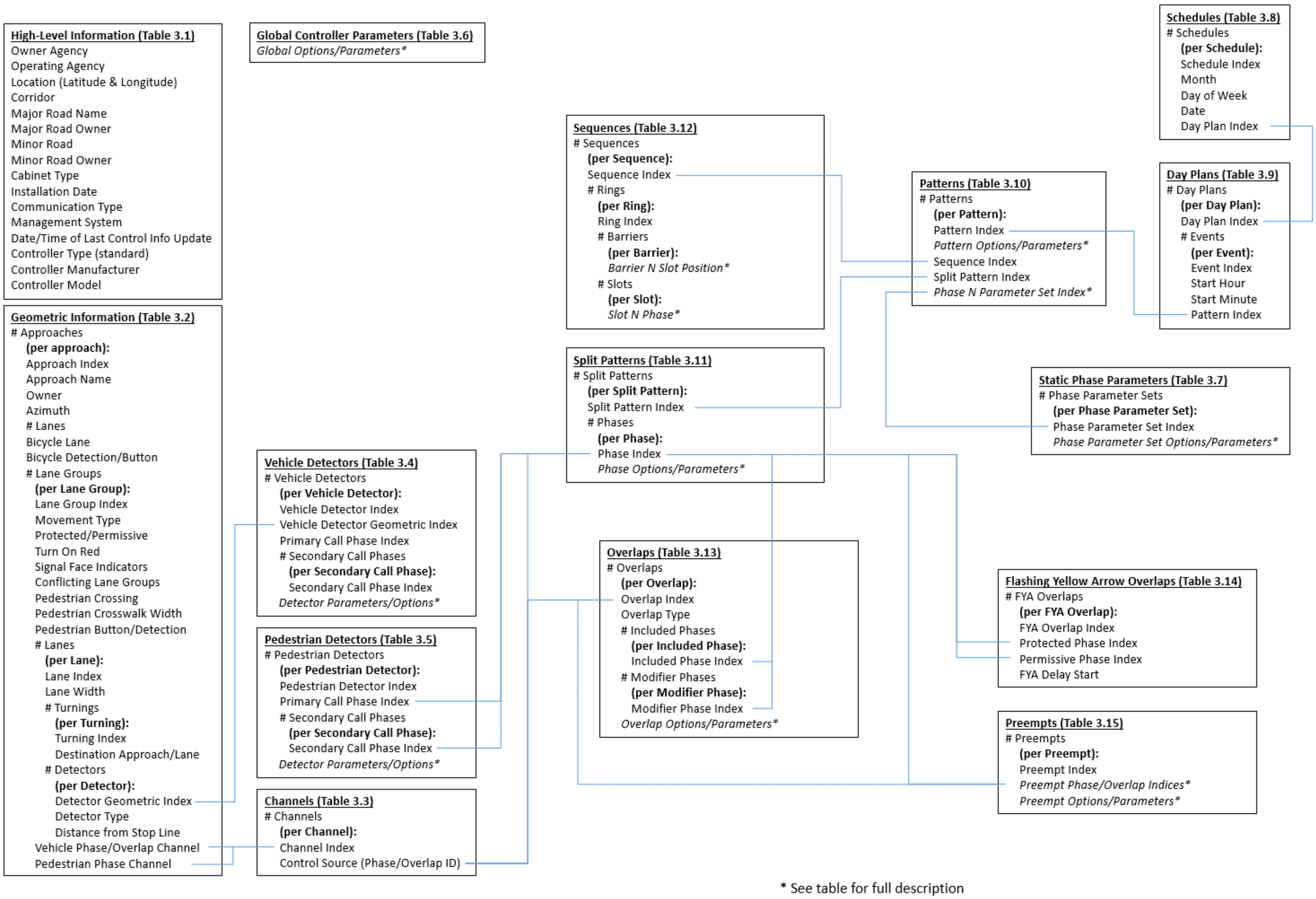


Figure 3.2 Graphical schema showing the organization of the unified set of intersection control information.

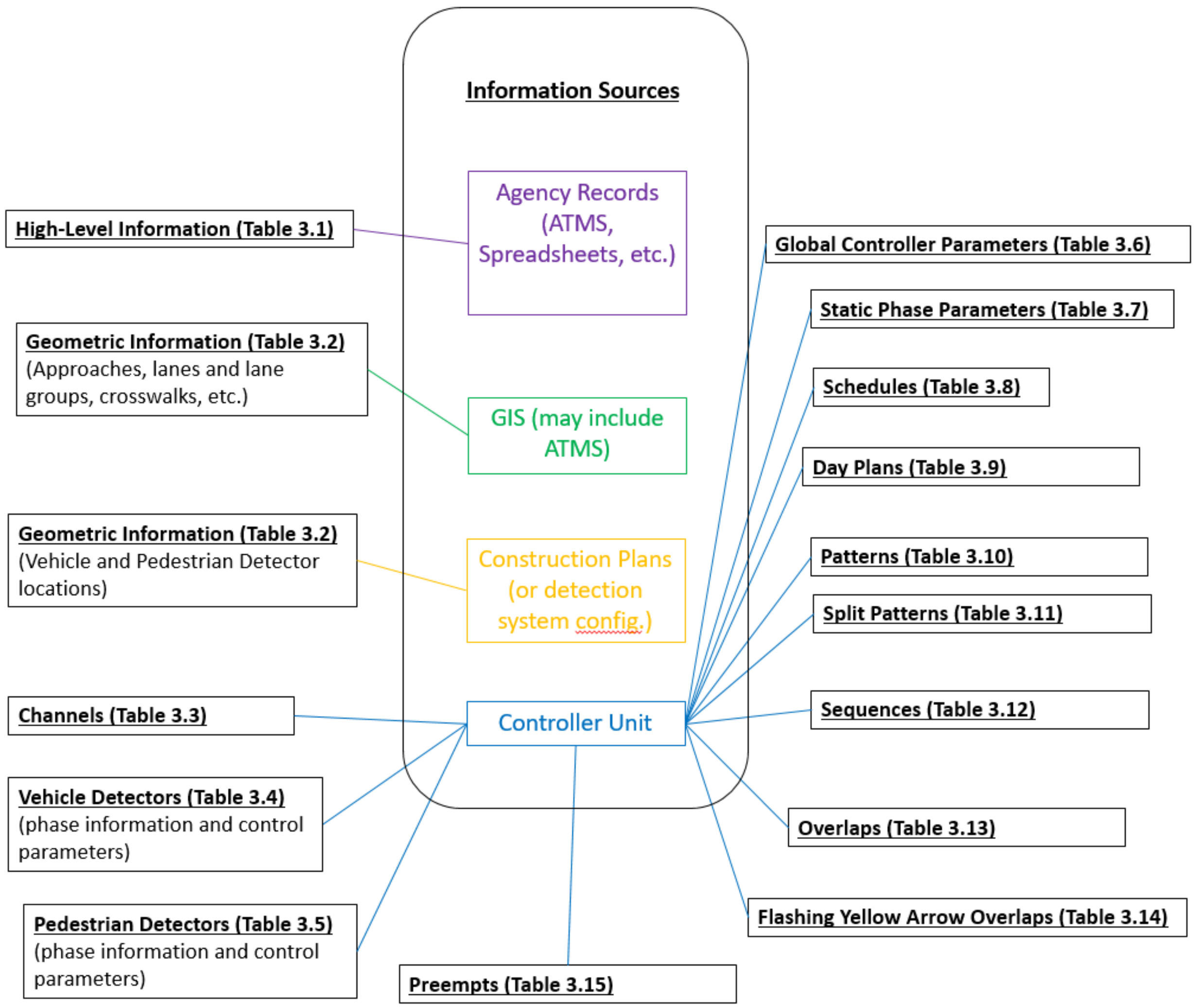


Figure 3.3 Information sources for the various components of the unified set of intersection control information.

CHAPTER 4: EXISTING STORAGE CAPABILITIES AND EXPANSION NEEDS

In addition to developing the unified set of intersection control information presented in the previous chapter, the other major task of this project involved determining the existing capabilities of management systems already in place and whether they could be adapted to store the information they do not already keep. This focused on the systems currently used by MnDOT for managing their traffic signals and collecting performance measures. For managing their traffic signals, MnDOT uses Intelight MaxView, a central traffic signal control system that provides an interface for administering signal controllers. This system has been in place since 2016 and has already helped advance the state of data management and collection at MnDOT. More recently, MnDOT has also begun using the open-source Automated Traffic Signal Performance Measures (ATSPM) system developed by the Utah Department of Transportation (UDOT) to collect high-resolution data for evaluating the performance of their traffic signals.

Both of these systems were considered as alternatives for storing the unified set of ICI that was developed in the hopes that it could save the effort of developing a custom solution. Regardless of the direction chosen, the proposed system had to be both centrally accessible by all agencies and approved modelers without concerns for firewalls, and would have to store the unified set of ICI for each intersection in a format that is easily readable by programs. These requirements strongly impacted this investigation and are reflected in the final recommendations.

4.1 METHODOLOGY

To determine the capabilities of the systems currently in use by MnDOT for managing their traffic signals, researchers took advantage of many resources provided by MnDOT and the developers of these systems, as well as their experience working with information technology systems. MnDOT's signal operations group was very open in working with researchers to explore the features of both MaxView and ATSPM, both by examining the user interface and the underlying databases they use to store information. In addition to this, Intelight, the developer of MaxView, very generously provided a trial version of MaxView and a signal controller unit for the duration of the project, allowing researchers to examine the flow of data in the program and database. Along with this MnDOT also provided an Econolite controller unit to show how MaxView interacts with the hardware that is most commonly installed by agencies in Minnesota (with some exceptions).

Over the course of the project, researchers worked with the MaxView server and signal controllers, MnDOT's signal operators, and Intelight representatives to learn how they system worked, how MnDOT used it, and the existing and potential capabilities for data storage and software-to-software translation tools. This involved reviewing the available technical documentation describing MaxView and attending a users' meeting to explore current and upcoming features, analyzing the database structure using the trial version and materials provided by MnDOT, and discussing how certain aspects of the program worked with Intelight developers to understand the capabilities of the system as it is currently implemented. MnDOT signal operators also helped by walking researchers through their common practices when using the system and how they use it to store information, respond to data requests, and carry out their regular audits of signal timing.

Similar to MaxView, researchers explored UDOT's open-source ATSPM software using similar techniques to understand its capabilities, how it works, and how it could be expanded. This consisted of reviewing the available documentation and presentations discussing how the system is used and reviewing the source code itself to understand how the system currently works and how it could be expanded. Along with this, the structure of the database used by ATSMP was analyzed using materials provided by MnDOT to determine what information could be obtained from it. Researchers also worked with the MnDOT engineer most involved in setting this system up to learn how they are using it and how it compares to and compliments MaxView. The information gathered from all these activities helped form the recommendations that are discussed in the following sections.

4.2 FINDINGS

During this project, researchers uncovered a number of important facts that affect the direction for the implementation phase of the project. While both MaxView and ATSPM contain much of the unified set of ICI proposed in the previous chapter, the needs of the programs are such that much of the detailed information needed for the development of simulation models is missing or unreadable. Information like the geographic location of an intersection, the different approaches, the number of lanes, and the position of detectors, among other things, are plainly available in the database. However, more detailed geometric information, such as the dimensions of lanes and crosswalks, the presence of bicycle lanes, and the curve radius of turns, among others, are not included. In addition to this, the structure of both databases can be convoluted at times, with many decisions likely made to benefit the organization of the programs at the expense of readability, which is understandable given that the databases are not intended to be used apart from the programs.

Most critically, however, is the lack of easily read signal programming information in the database. In ATSPM, much of this data is simply not included because it is not necessary for the program, which is more concerned with the collection of detector data and signal status information for generating performance measures. MaxView, by contrast, since it actually programs controllers, does contain detailed signal programming information, however it is not at all readable by anything besides MaxView itself. In the MaxView database, all signal programming information is contained in a "BinaryDatabases" table that holds a history of the programs that were pushed to the controllers. Each entry in this table is a binary serialized object that contains everything needed to program the controller, but it is encoded in a proprietary format. Because of this, any attempt to read this data would require a dedicated translation tool developed by Intelight, something that they have considered doing but do not have any immediate plans to do so.

4.3 RECOMMENDATIONS

Given these facts, using either MaxView or ATSPM as is to store the unified set of ICI is not feasible, as some of the critical information needed is either missing or not readable. Because of this, the best course for implementing a centralized system for warehousing ICI for multiple organizations involves the development of a custom solution for storing this information in a standardized format, along with the development of tools for reading this data from the available sources. What this system ultimately looks like can vary depending on what compatibility is included, how much manual effort for working with it is assumed, and what the interface(s) to the system are like, however some recommendations can be made to help in the decision making process.

To start, the system will need some sort of storage backend to physically store and organize the information. Probably the most straightforward solution for this is to use a relational database with a schema developed based on the unified ICI set presented in the previous chapter. Alternatively, a “NoSQL” database, such as a Key-Value Store, Object Database, or Document Store could be used instead which may provide more flexibility. Regardless, some sort of database would be an integral part of the system, providing a means for storing and serving the information in a convenient way. To support the requirement that multiple agencies and modelers be able to access this database, it would need to be hosted on a public network outside of any firewalls. A controlled interface with users and privilege management would be included to ensure the system is secure and that access can be controlled by the system administrators.

As for importing data into the database, there are two potential directions that would need to be discussed with stakeholders to choose the ideal solution. The issue at hand has to do with the accessibility of data from MaxView and ATSPM as discussed in the previous section. While general information about an intersection can be read directly from the program database, such as the geographic location, approaches, detector information, and connection parameters for the controller, the lack of detailed timing information in a readable format must be worked around in some way. One means for doing this would be to go to the controllers themselves to get the controller database and parse through the information there. This would require a custom tool that must be run from inside an agency’s firewall, reading general information about the intersections from the MaxView or ATSPM (or a different system) database, then using the controller connection information to download the database from each controller individually, parse the information, and upload everything to the central database. The tool could be run manually, be set to run periodically, or programmed to watch for changes to keep the information in the central database updated. This could likely take advantage of some of the tools developed by UDOT as part of the ATSPM software that contain code to handle reading the databases of common signal controllers.

Alternatively, the information needed could be obtained from MaxView or another CTSCS/ATMS system, without involving the controllers, if tools for exporting the data from these systems to the unified database in a specific format are added. This would of course require involvement from the developers of each system, which would likely come at a cost, however it would save the effort of developing the tools to communicate with the controllers. In the case of MaxView specifically, it currently does have the capability to export information about a signal to a spreadsheet in a flexible format, so a tool that exports this same data to a database in a different format would likely not be very difficult, but would require cooperation from Intelight. Discussions with Intelight representatives have shown that they are willing to consider this, as other organizations have expressed interest in being able to obtain controller program information from MaxView in a machine-friendly format. For other systems, however, the vendors may or may not be interested. In addition to MaxView, which is used by several agencies in the metro area in addition to MnDOT, Siemens TACTICS and Econolite Centracs are also common and used by some of the larger municipalities, such as Minneapolis (TACTICS) and St. Paul (Centracs) who operate hundreds of signals. Therefore, if this route were to be taken, involvement from these vendors would be essential.

There are also many smaller agencies that do not use a central system that would need to be considered, in addition to agencies that do not store all information in their CTSCS. In the case of agencies that do not use central systems, creating tools for importing U-ICI data directly from the controller may help ease the process, however because of differences in the output formats from different programs/systems this would require dedicated tools. For instance, while MaxView has the ability to export information from an Econolite controller in a format that is generally similar to the one output directly by the controller, there are some notable differences that would require the tools to be different. Aside from the difference in the file formats, issues like differences in the table structures, missing controller options, and changes in the order in which the control parameters are presented are all things that would require dedicated handling in software to use either format.

In addition to this, the mix of formats in used by smaller agencies presents a challenge. Spreadsheets can be easily read by an automated program, however understanding the organization of data in a spreadsheet is not trivial and the records can often be inconsistent. For PDF files and paper records, optical character recognition technology could be employed, however the same issues with organization and consistency arise. Ultimately, converting these records will require a multi-step process of manual cleaning of data to correct inconsistencies, documenting the format in a machine-readable way, and feeding the data into the central database via some custom software application. In some cases, it may also make sense to simply manually insert records into the database and establish provisions for regular updates.

Finally, in addition to the tools for importing data into the central database, some tools will need to be developed to export data from the central database into common formats and an interface for selecting what information is to be included. As was suggested by many of the respondents to the modeler survey, an interactive, web-based map interface is probably the most intuitive way to find the information needed, along with some form-based tools for extracting bulk amounts of data. As for the format in which the information will be output, the simplest thing would be a text (e.g. CSV) file that organizes the data in a predictable format. This would at least provide input for an automated translation tool that could be developed by modelers or the vendors of the programs they use. As an alternative that is perhaps more easy to work with, Synchro files containing signal program information are already directly importable into many modeling programs and would probably be a worthwhile format to make available. This leaves out geometric information, which could be placed into a geodatabase or shapefile container, which many programs are also able to read. Also regardless of any machine-readable formats, a clear, human-readable report format, such as the one presented in Figure 4.1, would also be useful for signal operators and others familiar with these types of documents.

MnDOT Highway 7 - 2018 --- WEST
OPTIMIZED

INTID: 130 TH 7 and TH 41 COMM ID: 3

Phase	1	2	3	4	5	6	7	8	9
Front Page Timing									
Direction	WBL	EBT	NBL	SBT	EBL	WBT	SBL	NBT	WBL2
Left Turn Type	Prot				Prot				
Min Green	7	15	5	7	7	15	5	7	7
Max Green	40	80	30	50	20	80	30	50	40
Walk	-	-	-	21	-	7	-	-	-
Flash. Don't Walk	-	-	-	19	-	18	-	-	-
Yellow	3.0	5.5	3.0	5.5	3.0	5.5	3.0	5.5	3.0
All Red	3.0	1.5	2.5	3.0	3.0	1.5	2.5	2.0	3.0
Vehicle Extension	3.0	5.5	3.0	3.0	3.0	5.5	3.0	4.0	3.0
Time Before	-	30.0	-	-	-	-	-	30.0	-
Time to Reduce	-	20.0	-	-	-	-	-	20.0	-
Min Gap	-	3.0	-	-	-	-	-	3.0	-
Recall Mode	-	Min	-	-	-	Min	-	-	-
Min Split Synchro	15	23	13	15	15	23	13	15	15
Min Split Ped	-	-	-	49	-	33	-	-	-
Min Split Veh	15	23	13	16	15	23	13	15	15
Min Split Phasing	15	18	15	15	15	18	15	15	15

Pattern	1	2	3	4	5	6	7	8
Peak	-	**AM2**	**AM1**	**BAL2**	**BAL1**	**PM2**	**PM1**	**BAL3**
Cycle	-	**160**	**240**	**110**	**130**	**170**	**220**	**110**
Coord Timing								
Cycle	-	160	240	110	130	170	220	110
COS	-	-	-	-	-	-	-	-
Offset	-	81	97	64	77	106	63	52
Phase 1 WBL	-	-	15	-	35	23	20	-
Phase 2 EBT	-	66	109	50	35	48	82	38
Phase 3 NBL	-	19	26	14	16	31	38	23
Phase 4 SBT	-	30	47	18	22	26	30	21
Phase 5 EBL	-	15	23	15	16	18	20	15
Phase 6 WBT	-	96	144	63	76	95	132	51
Phase 7 SBL	-	19	14	14	17	21	20	16
Phase 8 NBT	-	30	59	18	21	36	48	28
Phase 9 WBL2	-	45	43	28	22	42	50	28
Coord Phase(s)	-	26+	26+	26+	26+	26+	26+	26+
Lag Left Phase(s)	-	-	-	-	-	5	-	-
ASC/3 Sequence	-	1	1	1	1	5	1	1
Omitted Phase(s)	-	1	-	1	-	-	-	1
Recalls								

Figure 4.1 Example of a human-readable report format for signal timing information (SRF Consulting Group, Inc.)

All of these factors will need to be taken into account to make an informed decision as to the best path for implementation. While MnDOT is both the priority and the best equipped to make their ICI available in a centrally accessible system, the nature of the transportation network and its overlapping jurisdictions mean that the needs and practices of other agencies must also be considered. The first priority would be deciding on the database implementation that is used, followed by what tools will be developed to automate the data collection process, something that will be influenced by the systems and practices of other agencies. After that, any interface and export tools that would be part of the system would need to be decided. Once the needed development has been completed, the process for carrying out the collection and importation into the central database can be carried out, with quality control provisions to insure the integrity of the data in the system. A more thorough outline of this process will be provided in the work plan that is developed as the final project deliverable.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The project described in this report began as part of a larger plan that included the development of the proper container/host for the U-ICI as well as to identify, and when possible build, the interface tools required to allow secure exchange of information between the central control systems owned by the various jurisdictions and U-ICI repository. For efficiency and to prioritize on feasibility, the plan was split into two phases. The first phase, this project, was to identify the ICI user needs, and based on these, develop the U-ICI proposed structure that satisfies them. In this first phase the research team was also tasked to investigate the feasibility of using a commercially available central control system as the U-ICI repository, focusing primarily on the system MnDOT recently transitioned to, Maxview from Intelight.

The purpose of this chapter is to conclude the effort on Phase I by offering recommendations on how to proceed with Phase II of the proposed effort. The ultimate goal is to allow any interested entity to retrieve the most up-to-date and complete sets of U-ICIs for signalized intersections anywhere in the Twin Cities metropolitan area and possibly beyond. This goal carries the following requirements:

- The ICI available to external entities should be comprehensive enough to satisfy all known and identified uses for such information. In other terms, the provided information, at a minimum, must contain all the pieces of information described in the U-ICI developed in this project.
- The transfer of U-ICI to external entities must not violate the safety and security of the organization that owns the signals related to the requested U-ICI. This means that there is either a secure socket providing a limited access through the institutions firewall or the U-ICI repository resides outside any entity that owns/operates traffic signals.
- The request and retrieval of the requested U-ICI must result in minimal effort by the traffic operations group in the organization that owns the relevant signals. This can be accomplished in two ways:
    - Through dedicated interfaces that allow outside entities to send data requests to the owner's central control system
    - Manual or scheduled "push" events initiated by each central control system directing new or updated U-ICI to the common repository
- The available U-ICI must be current and describe the operating parameters of the traffic signals at the time of the request. This means that if the update of U-ICI is performed manually, the owner organization needs to ensure that this happens every time something changes.
- Availability of historical U-ICI. Although this can be considered an optional feature, in many cases, especially in modeling projects, it is more important to retrieve the U-ICI that were current during the collection of other needed information (turning moving counts, past special event data collections, etc.) This covers the cases where the U-ICI for a particular group of intersections changed between the time demand was measured and the time the modeler encountered the need to retrieve U-ICI for the model under development. To cover this need, if the U-ICI are extracted from the owners central control system, past versions of the operating parameters need to be saved and maintained. If the U-ICI reside in an external repository, such database needs to be designed to include a time period for which its set of U-ICI information is valid.

As presented in Chapter 4, without the cooperation of the software developers, it is not easy or even feasible to expand the proprietary databases used by the current version of Maxview and the rest of the control software used by jurisdictions in the Twin Cities metropolitan area to include the additional information that is part of the U-ICI. Given that any piece of software can be modified to cover any new functionality if cost and effort is not an issue, this task becomes possible if undertaken by the developers. Indeed, in discussions that took place during the time this chapter was composed, due to customer pressure, Intelight reportedly initiated changes in Maxview to satisfy the input and storage of some of the missing information that constitute the difference between the ICI currently stored in Maxview and the U-ICI as defined in this project. Naturally, because other states/clients of Intelight are driving these developments, it is unknown as to what degree the additional information stored will come to the full U-ICI set Minnesota's stakeholders need.

Regardless, even if Maxview and any of the other central control systems, such as TACTICS, Spinnaker, Aries, Centracs, and Miovision, that are currently used in Minnesota do expand their databases and user interfaces to allow input and storage of all pieces of information included in the U-ICI, the problem of secure and effortless data exchange remains more or less the same. Realistically, all of these products compete in the market and it is not in their best interest to allow the users to consider them as interchangeable applications. Case in point, even the approved NTCIP standard set of information is not completely supported in terms of transferring information between two of the aforementioned software applications.

In regard to the method for storing and disseminating U-ICI, it is the recommendation of this project that a repository (database), external from that of any jurisdiction, is the most efficient, secure, and long lasting solution. In IT jargon, such a repository is in the loud. For the less IT-savvy reader, though, let's clarify some potential misconceptions.

- There is no such thing as the "cloud". The Internet is comprised of billions of individual computers owned by physical entities and residing in physical locations, all possessing the ability to communicate with each other.
- In its majority, the aforementioned computers are owned by individuals and organizations that keep access to their data restricted and access to their machines secured to prevent unauthorized uses. These safeguards are collectively described as firewalls. Computers that are behind such firewalls have the ability to receive and send information to other computers outside their firewall as long as this communication is initiated from the inside. So, from your computer, you can reach out to billions of machines around the world but only specific machines/users from the outside, that you have specifically authorized, can access your computer.
- To maintain efficient exchange of information without compromising security, selected computers are left open with minimal firewalls protecting them. Other computers, can exchange data by using these open computers as the middle station. These facilities have been collectively named the "cloud".

So to bring the subject back to the topic of this report, the Cloud repository of U-ICI is simply a database or library residing on a computer that is outside of any particular jurisdiction's firewall. That computer can be leased by a cloud provider like Amazon, Google, and others or it can simply be a regular PC residing in an office in MnDOT or MNIT connected to the Internet outside the MnDOT firewall. The reason services like Amazon and others have become popular is that leasing a computer from them relieves you from the effort of maintaining the actual machine and keeping it operational. Given that these machines are open to the world, they have higher frequencies of malicious attacks by hackers and other bad elements so they require more than the average maintenance effort.

Having clarified that a repository in the “cloud” is hardly different than a database on any ordinary PC, let’s discuss required resources. Two types of computer resources are relevant in this case storage capacity and communication bandwidth. In either case, as long as U-ICI covers only static information and does not include dynamic information similar to that included in the SPaT messages or include traffic measurements, the requirements for storage and bandwidth are minimal. The entire detector data from the entire RTMC detection infrastructure updated every 30 seconds and stored in a database since 1994 only takes less than 70GB of disk space. This is less than a blue ray movie with a two-hour duration. The collected U-ICI from every signal in the entire state of Minnesota constitutes a tiny fraction of the aforementioned disk space. Also, given that the static U-ICI information for the average traffic signal changes once a year or even less frequently, the number of requests for this information is similarly sparse. In conclusion, selecting a cloud repository as the “middle man” in the exchange of U-ICI requires little in resources.

The expense in time and effort in establishing a cloud repository of U-ICI is mainly in the development of the utilities residing on the protected machines running the instances of Maxview, Tactics, etc. handling the automatic/scheduled synching of information between each jurisdiction’s system and the cloud repository, as well as the user interface of said repository that would allow querying the repository for U-ICI from selected intersections. Figuring out the design of such utilities and interfaces is in the scope of the second phase of this project.

We hope that the work performed in this project identified the needs of the different stakeholder groups, produced an organized and comprehensive format for intersection control information that contains most, if not all, the information any group needs and has demystified the resources and effort required to establish a U-ICI repository that can form the distribution node of such information without affecting the security of any operational system.

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APPENDIX A
SURVEY FOR TRAFFIC SIGNAL OWNERS AND OPERATORS

Identifying Information

As part of a MnDOT-sponsored project, the University of Minnesota is evaluating the options and best practices for implementation of a Central Traffic Signal Database to allow greater interoperability between signal owners and other stakeholders, such as traffic modelers and planners, who might regularly need access to detailed intersection control information.

To inform this effort, researchers are surveying traffic signal owners and operators to determine what kind of information they collect about their signals and how this information is stored. In addition to this, researchers are separately surveying traffic modelers, planners, and others who use intersection control information as part of their work to determine what kind of information they need and how they use it. Together, the results of these surveys will be used to help develop a unified set of intersection control information that is feasible to collect and that satisfies the needs of various applications.

Once the survey results have been collected, researchers will select a small number of participants to interview to obtain more details regarding their current practices and needs. Your responses below will be used to determine if you should be included in these interviews.

If you have any questions regarding the survey or this research, please contact mtolab@umn.edu or kevin.schwartz@state.mn.us for more information.

This survey should take less than 15 minutes to complete. Your participation is greatly appreciated.

What is your name and title/role?

What organization/agency/municipality do you represent?

What level of jurisdiction does your organization serve?

- State
- County
- City

What role do you serve at this organization? Select all that apply.

- Signal Design
- Signal Operations/Optimization
- Traffic Operations
- Maintenance
- Manager/Supervisor
- Other (please specify)

Do you own, operate, or otherwise work with traffic signals?

- Yes
- No

General Signal Information

For signals you own or operate, does your organization maintain digital or paper records of the following information? Select all that apply.

- Signal owner (if not your organization)
- Communication capabilities (i.e. network connection to the cabinet)
- Date of last update to traffic control information

In what format are these records maintained? Select all that apply.

- [ ] GIS/Geodatabase
- [ ] Database Application (e.g. Microsoft SQL Server, PostgreSQL, etc.)
- [ ] Spreadsheets
- [ ] PDF files of digital documents
- [ ] PDF files of scanned documents
- [ ] Paper records
- [ ] Other (please specify)

Intersection Geometry

Do you maintain records of Geo-locations (i.e. latitude and longitude) of your intersections?

- ( ) Yes
- ( ) No

In what format is this information typically stored? Select all that apply.

- [ ] Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- [ ] Closed-Loop Traffic Control System (e.g. Aries, etc.)
- [ ] GIS/Geodatabase
- [ ] Database Application (e.g. Microsoft SQL Server, PostgreSQL, etc.)
- [ ] Spreadsheets
- [ ] Construction plans
- [ ] PDF files of digital documents
- [ ] PDF files of scanned documents
- [ ] Paper records
- [ ] Synchro
- [ ] Other software (please provide name and version)
- [ ] Other (please specify)

Do you maintain records of detector locations at your intersections?

- Yes
- No

In what format is this information typically stored? Select all that apply.

- Construction plans
- PDF files of digital documents
- PDF files of scanned documents
- Paper records
- Spreadsheets
- Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- Closed-Loop Traffic Control System (e.g. Aries, etc.)
- GIS
- Synchro
- Other software (please provide name and version)
- Other (please specify)

Do you maintain records of detector-phase assignments?

- Yes
- No

In what format is this information typically stored? Select all that apply.

- Construction plans
- PDF files of digital documents
- PDF files of scanned documents
- Paper records
- Spreadsheets

- ☐ Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- ☐ Closed-Loop Traffic Control System (e.g. Aries, etc.)
- ☐ GIS
- ☐ Synchro
- ☐ Other software (please provide name and version) ________
- ☐ Other (please specify) ________

Isolated Signal Information

Do you maintain records of the type of control used at an intersection (e.g. pre-timed, semi-actuated, fully-actuated)?

- ○ Yes
- ○ No

In what format is this information typically stored? Select all that apply.

- ☐ Construction plans
- ☐ PDF files of digital documents
- ☐ PDF files of scanned documents
- ☐ Paper records
- ☐ Spreadsheets
- ☐ Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- ☐ Closed-Loop Traffic Control System (e.g. Aries, etc.)
- ☐ GIS
- ☐ Synchro
- ☐ Other software (please provide name and version) ________
- ☐ Other (please specify) ________

Do you maintain records of the program schedule in place at an intersection?

- ○ Yes

○ No

In what format is this information typically stored? Select all that apply.

- ☐ Construction plans
- ☐ PDF files of digital documents
- ☐ PDF files of scanned documents
- ☐ Paper records
- ☐ Spreadsheets
- ☐ Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- ☐ Closed-Loop Traffic Control System (e.g. Aries, etc.)
- ☐ GIS
- ☐ Synchro
- ☐ Other software (please provide name and version) ________
- ☐ Other (please specify) ________

Do you maintain records of the signal timing information for each program?

- ○ Yes
- ○ No

In what format is this information typically stored? Select all that apply.

- ☐ Construction plans
- ☐ PDF files of digital documents
- ☐ PDF files of scanned documents
- ☐ Paper records
- ☐ Spreadsheets
- ☐ Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- ☐ Closed-Loop Traffic Control System (e.g. Aries, etc.)
- ☐ GIS
- ☐ Synchro

- [ ] Other software (please provide name and version) ______
- [ ] Other (please specify) ______

Do you maintain records of features such as Transit Signal Priority (TSP) or Emergency Vehicle Preemption (EVP) present at your intersections?

- ○ Yes
- ○ No

In what format is this information typically stored? Select all that apply.

- [ ] Construction plans
- [ ] PDF files of digital documents
- [ ] PDF files of scanned documents
- [ ] Paper records
- [ ] Spreadsheets
- [ ] Central Traffic Signal Control Systems (e.g. MaxView, Aries, etc.)
- [ ] GIS
- [ ] Synchro
- [ ] Other software (please provide name and version) ______
- [ ] Other (please specify) ______

Do you maintain real-time records of signal timing information that is currently active in the field?

- ○ Yes
- ○ No

In what format is this information typically stored? Select all that apply.

- [ ] Construction plans
- [ ] PDF files of digital documents

- [ ] PDF files of scanned documents
- [ ] Paper records
- [ ] Spreadsheets
- [ ] Central Traffic Signal Control Systems (e.g. MaxView, Centracs, etc.)
- [ ] Closed-Loop Traffic Control System (e.g. Aries, etc.)
- [ ] GIS
- [ ] Synchro
- [ ] Other software (please provide name and version) ______
- [ ] Other (please specify) ______

Coordinated Signal Information

Do you own or operate any coordinated signals?

- ○ Yes
- ○ No

For the coordinated signals you own/operate, do you maintain records of the type of coordination in place?

- ○ Yes
- ○ No

In what format is this information typically stored? Select all that apply.

- [ ] Construction plans
- [ ] PDF files of digital documents
- [ ] PDF files of scanned documents
- [ ] Paper records
- [ ] Spreadsheets
- [ ] Central Traffic Signal Control Systems (e.g. MaxView, Aries, etc.)
- [ ] GIS

- [ ] Synchro or other software (please provide name and version)
- [ ] Other (please specify)

Central Traffic Control System

Does your organization use a Central Traffic Signal Control System (CTSCS) or Advanced Traffic Management System (ATMS) (e.g. MaxView, Centracs, etc.) for managing your signals?

- ○ Yes
- ○ No

What system does your organization use?

- ○ MaxView (Intelight)
- ○ Centracs (Econolite)
- ○ Miovision
- ○ TACTICS (Siemens)
- ○ Spinnaker (Peek)
- ○ Other (please specify)

Do you use this system to store any geometric information relating to the intersections? Select all that apply.

- [ ] Intersection Geo-location (latitude/longitude)
- [ ] Detector locations
- [ ] Phase-detector assignments
- [ ] Other (please specify)

Does this system provide real-time intersection control information?

- ○ Yes

○ No

Why does your organization use this particular system? Do you have any other comments on the system your organization uses?

Traffic Measurements

Do you collect any traffic measurements from your intersections such as volume counts, recorded splits, etc.?

○ Yes
○ No

Do you collect real-time or near real-time traffic measurements at your intersections? If you collect both real-time and near real-time data (for example if higher resolution data is available less frequently), please indicate so by selecting both choices.

☐ Yes, real-time (within time frames of less than 1 minute)
☐ Yes, near real-time (within time frames between 1 minute and 1 hour)
☐ No

At what level of resolution/aggregation is this data collected?

☐ Individual detector actuations
☐ Aggregated in intervals up to 15 minutes
☐ Aggregated hourly
☐ Other

Do you maintain historical traffic measurements at your intersections?

- ○ Yes
- ○ No

At what level of resolution/aggregation is this data collected?

- ☐ Individual detector actuations
- ☐ Aggregated in intervals up to 15 minutes
- ☐ Aggregated hourly
- ☐ Other ____________

How long do you typically store the traffic measurements collected from your intersections?

- ○ Less than 1 week
- ○ Between 1 week and 1 month
- ○ Between 1 and 3 months
- ○ Longer than 3 months

In what format do you store the traffic measurements collected from your intersections? Select all that apply.

- ☐ Central Traffic Signal Control System/Advanced Traffic Management System
- ☐ Signal Performance Measure System (e.g. UDOT ATSPM)
- ☐ Database Application (e.g. Microsoft SQL Server, PostgreSQL, etc.)
- ☐ Spreadsheets
- ☐ PDF files of digital documents
- ☐ PDF files of scanned documents
- ☐ Paper records
- ☐ Other (please specify) ____________

Additional Information Collected

Aside from the information mentioned in the previous sections, is there any other information your organization collects about your signals that you find useful in the course of your operations?

Need for Intersection Information from Other Organizations

Do you need, or would you benefit from having a simple way of accessing the following information concerning signals owned/operated by other organizations? Select all that apply.

- ☐ Intersection geometry (detector locations, phase assignments, etc.)
- ☐ Communication capabilities (i.e. network connection to the cabinet)
- ☐ Date of last traffic control information update
- ☐ Traffic control information (type of control, program schedule, timing information, coordination, etc.)
- ☐ Use of a Central Traffic Signal Control System or Advanced Traffic Management System
- ☐ Traffic measurements

If available, would you use real-time or near real-time traffic measurements collected from intersections owned by other organizations to help improve the performance of signals you own/operate?

- ○ Yes
- ○ Maybe
- ○ No

If available, would you use historical traffic measurements collected from intersections owned by other organizations to help improve the performance of signals you own/operate?

- ○ Yes
- ○ Maybe
- ○ No

Aside from the information above, is there any other information that other organizations could provide about their signals to help you operate your signals?

Information Requests

In the past, have any organizations (public or private) approached your organization to request information about your signals or related traffic measurements?

- ○ Yes
- ○ No

In the last year, which of the following groups have approached your organization to request this information? Select all that apply.

- ☐ Consultants (e.g. SRF, Alliant Engineering, etc.)
- ☐ Traffic Information Providers (e.g. Google, INRIX, etc.)
- ☐ Other Jurisdictions (MnDOT, counties, or cities)
- ☐ Construction Planners or Work Zone Traffic Control Planners

- [ ] Planning Organizations (e.g. Metropolitan Council)
- [ ] Transit Organizations (e.g. Metro Transit)
- [ ] Data Practice Requests (e.g. lawyers, insurance companies, etc.)
- [ ] Other (please specify) ______

Additional Information

Please enter any additional comments you have below.

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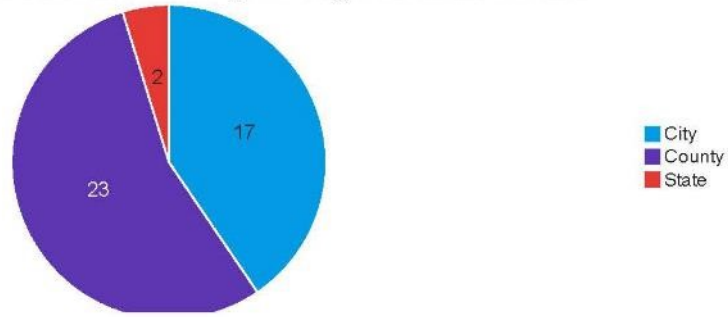
APPENDIX B
RESPONSE DATA FROM TRAFFIC SIGNAL OWNERS AND OPERATORS SURVEY

Q1 - What organization/agency/municipality do you represent?

What organization/agency/municipality do you represent?
City of Burnsville
shakopee
Steele County
Sherburne County Public Works
City of Ramsey
City of Coon Rapids
Beltrami County
Carver County
Lac qui Parle County
Scott County
Kandiyohi Co.
Watonwan County Public Works
Benton County
Mille Lacs County
City of Rochester
Otter Tail County
City of Shoreview
Dakota County
Edina
MnDOT

Q2 - What level of jurisdiction does your organization serve?

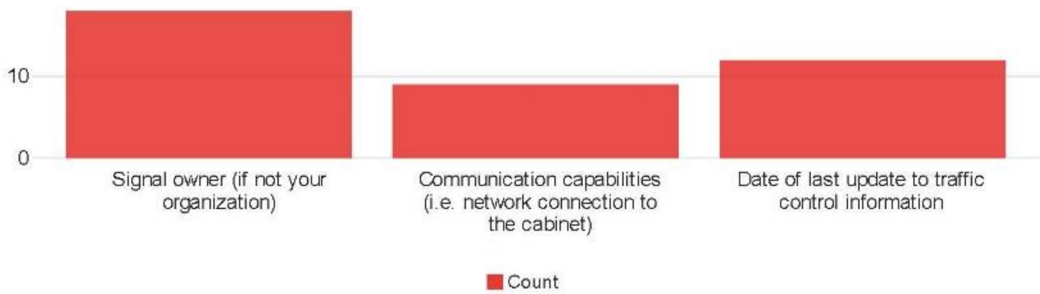


Q3 - What role do you serve at this organization? Select all that apply. - Selected Choice

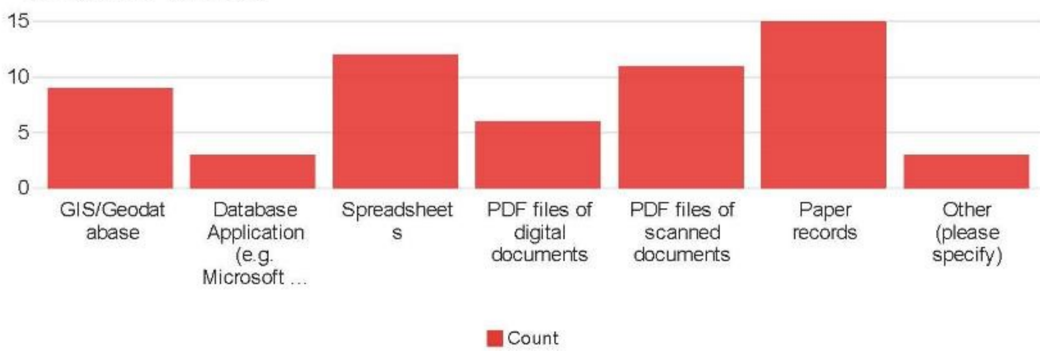
Q3_5_TEXT - Other (please specify) - Text

Other (please specify) - Text
Traffic Liason
Assistant County Engineer
Engineering
Signal/Lighting Contact
County Engineer
County Engineer
City Engineer
Public Works Director
County Engineer

Q4 - For signals you own or operate, does your organization maintain digital or paper records of the following information? Select all that apply.



Q5 - In what format are these records maintained? Select all that apply. - Selected Choice

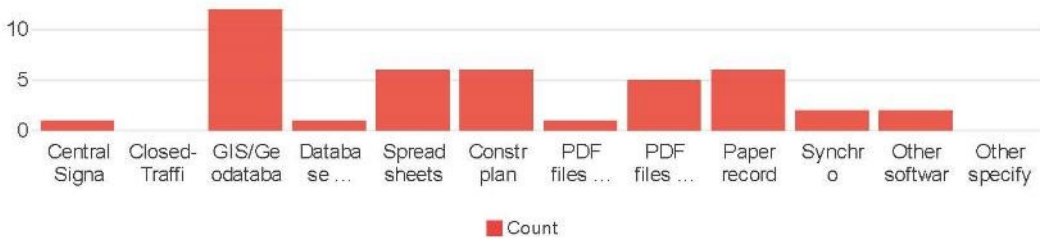


Q5_64_TEXT - Other (please specify) - Text

Other (please specify) - Text
Aries software
MnDOT maintains the controls and may have these records.
Centracs

Q12 - Do you maintain records of Geo-locations (i.e. latitude and longitude) of your intersections?

Q13 - In what format is this information typically stored? Select all that apply. - Selected Choice

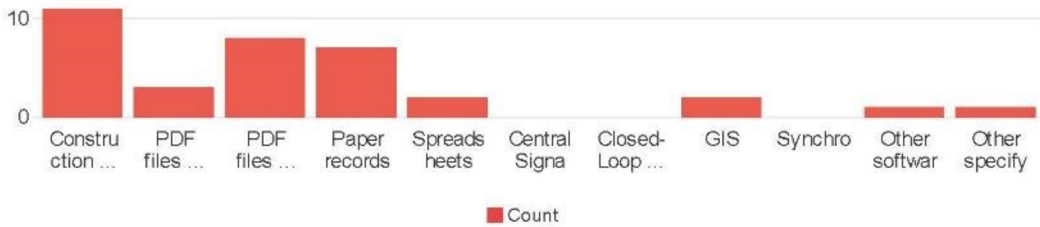


Q13_78_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
aries
Cartegraph

Q8 - Do you maintain records of detector locations at your intersections?

Q9 - In what format is this information typically stored? Select all that apply. - Selected Choice



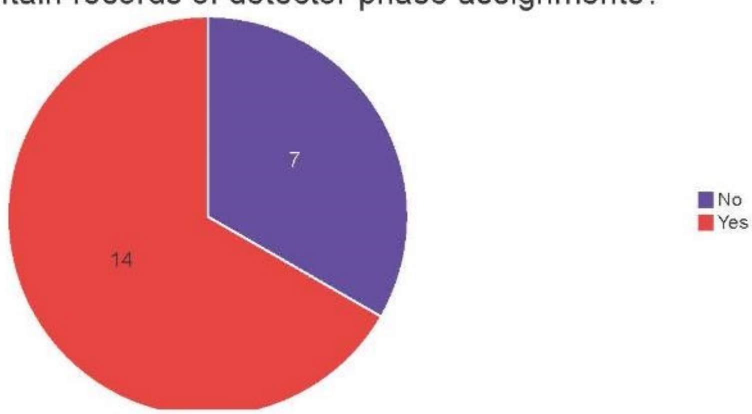
Q9_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
Cartegraph

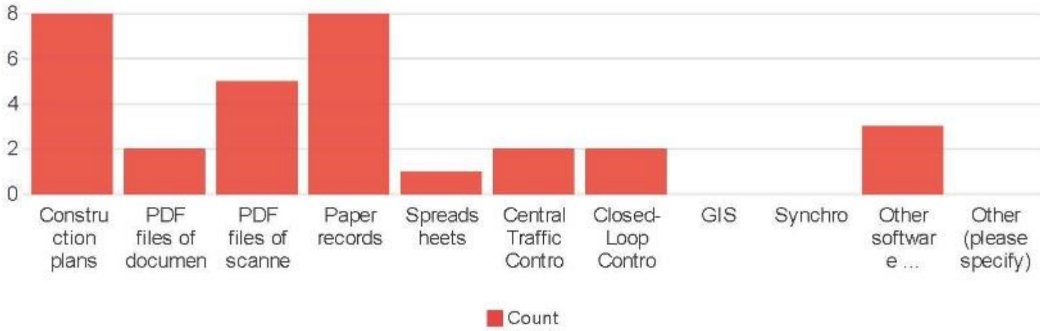
Q9_9_TEXT - Other (please specify) - Text

Other (please specify) - Text
video detection zones on vendor software

Q10 - Do you maintain records of detector-phase assignments?



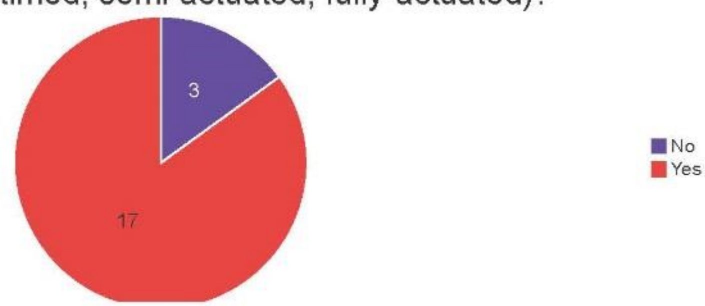
Q11 - In what format is this information typically stored? Select all that apply. - Selected Choice



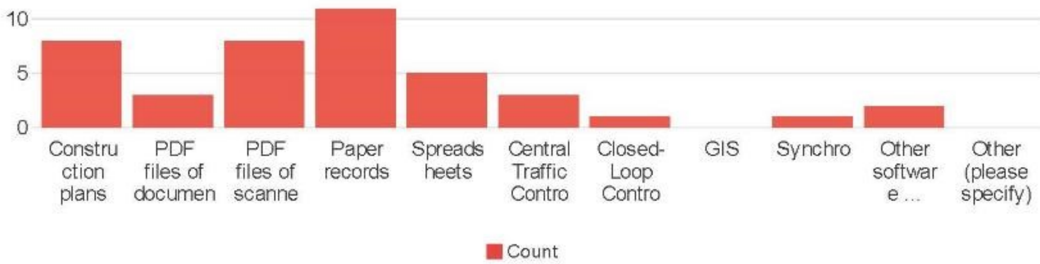
Q11_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
aries
Cartegraph
Autoscope

Q14 - Do you maintain records of the type of control used at an intersection (e.g. pre-timed, semi-actuated, fully-actuated)?



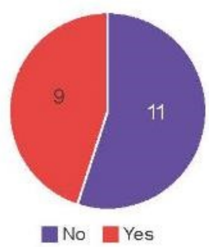
Q16 - In what format is this information typically stored? Select all that apply. - Selected Choice



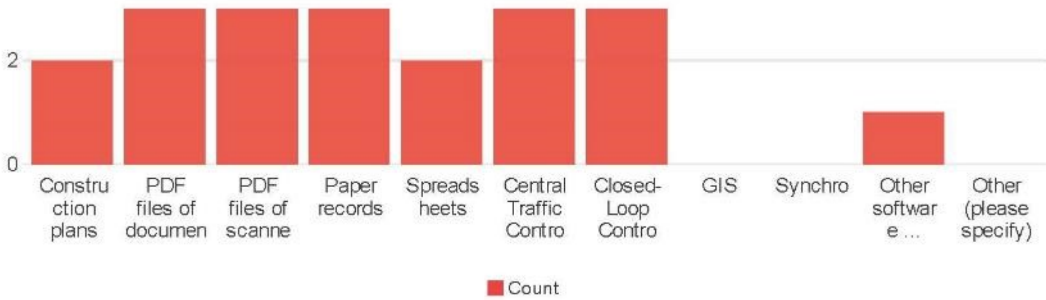
Q16_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
aries
Cartegraph

Q17 - Do you maintain records of the program schedule in place at an intersection?



Q18 - In what format is this information typically stored? Select all that apply. - Selected Choice



Q18_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
Cartegra[h

Q19 - Do you maintain records of the signal timing information for each program?

Q20 - In what format is this information typically stored? Select all that apply. - Selected Choice

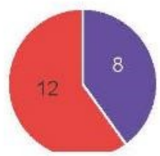
Q20_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
aries
Cartegraph

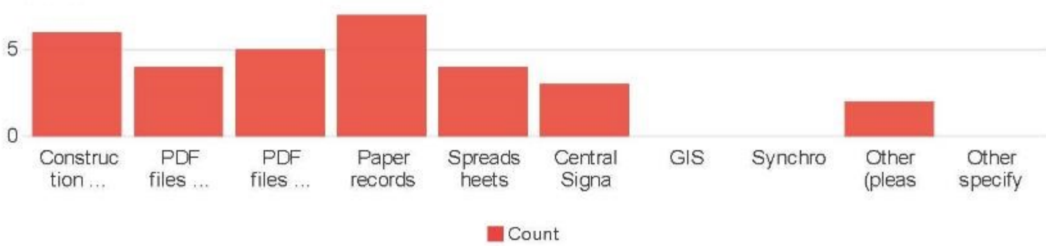
Q20_9_TEXT - Other (please specify) - Text

Other (please specify) - Text
consultant

Q46 - Do you maintain records of features such as Transit Signal Priority (TSP) or Emergency Vehicle Preemption (EVP) present at your intersections?



Q48 - In what format is this information typically stored? Select all that apply. - Selected Choice

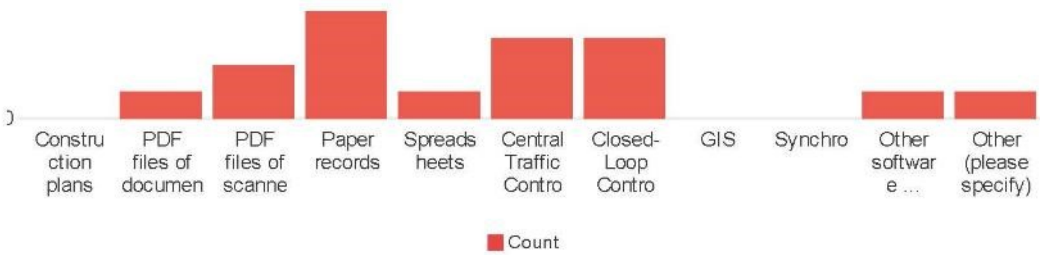


Q48_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
aries
Cartegraph

Q49 - Do you maintain real-time records of signal timing information that is currently active in the field?

Q50 - In what format is this information typically stored? Select all that apply. - Selected Choice



Q50_8_TEXT - Other software (please provide name and version) - Text

Other software (please provide name and version) - Text
Cartegraph

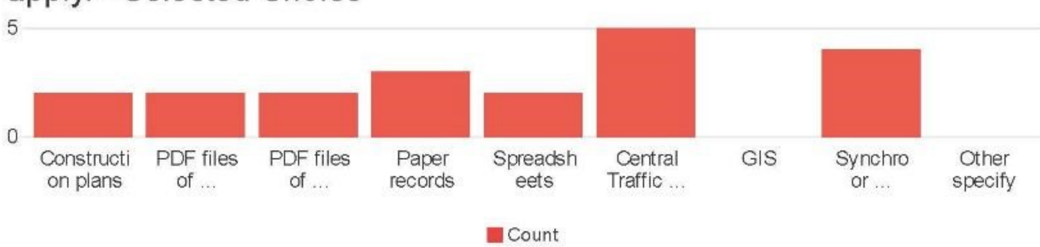
Q50_9_TEXT - Other (please specify) - Text

Other (please specify) - Text
If field adjustments are made, it is written in a cabinet log book.

Q21 - Do you own or operate any coordinated signals?

Q22 - For the coordinated signals you own/operate, do you maintain records of the type of coordination in place?

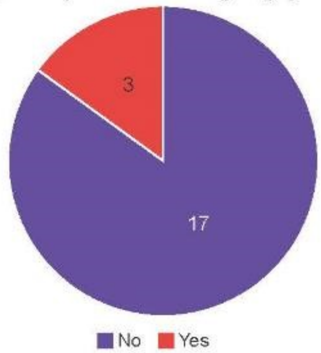
Q24 - In what format is this information typically stored? Select all that apply. - Selected Choice



Q24_8_TEXT - Synchro or other software (please provide name and version) - Text

Synchro or other software (please provide name and version) - Text
aries
Synchro 9 but converting up to version 10

Q29 - Does your organization use a Central Traffic Signal Control System (CTSCS) or Advanced Traffic Management System (ATMS) (e.g. MaxView, Centracs, etc.) for managing your signals?



Q30 - What system does your organization use? - Selected Choice

Q31 - Do you use this system to store any geometric information relating to the intersections? Select all that apply. - Selected Choice

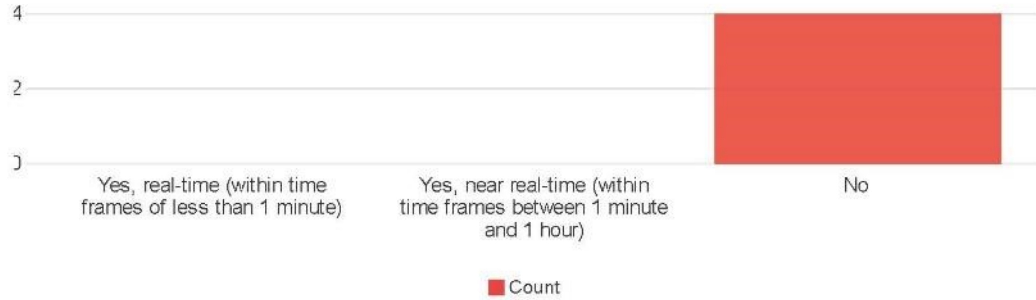
Q51 - Does this system provide real-time intersection control information?

Q52 - Why does your organization use this particular system? Do you have any other comments on the system your organization uses?

Why does your organization use this particular system? Do you have any other comments on the system your organization uses?
It is proprietary to Siemens and we have had some version of it since before NTCIP was around.
Seemed to be the best fit for us and that was reinforced when it was selected by MnDOT
We have been using the Econolite Central Systems for over 15 years. We know it will work with Econolite controllers.

Q32 - Do you collect any traffic measurements from your intersections such as volume counts, recorded splits, etc.?

Q33 - Do you collect real-time or near real-time traffic measurements at your intersections? If you collect both real-time and near real-time data (for example if higher resolution data is available less frequently), please indicate so by selecting both choices.

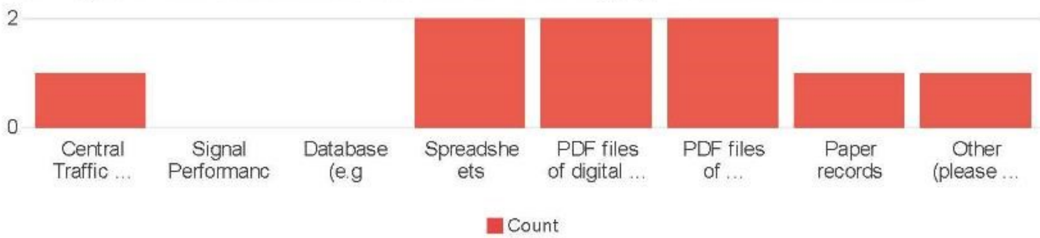


Q34 - Do you maintain historical traffic measurements at your intersections?

Q38 - At what level of resolution/aggregation is this data collected? - Selected Choice

Q35 - How long do you typically store the traffic measurements collected from your intersections?

Q40 - In what format do you store the traffic measurements collected from your intersections? Select all that apply. - Selected Choice



Q40_8_TEXT - Other (please specify) - Text

Other (please specify) - Text
Miovision

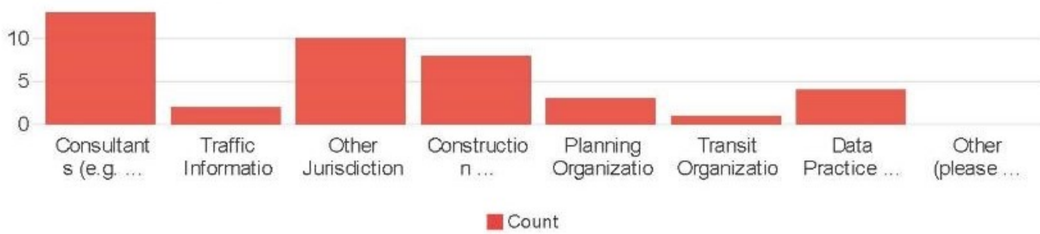
Q38 - Aside from the information mentioned in the previous sections, is there any other information your organization collects about your signals that you find useful in the course of your operations?

Aside from the information mentioned in the previous sections, is there any other information your organization collects about your signals that you find useful in the course of your operations?
The controller timing was set by the Traffic Engineer who designed them and all three have a fixed program.
All work done inside the cabinet and out in the field.
We only have 2 signals that the County owns 100% and they are relatively new (less than 5 yr). Other signals that we "maintain" are owned by MNDOT.
Handhole locations are recorded in GIS for use in winter field locates, along with other point data such as pole foundations.

Using Miovision to do travel time analysis on several corridors

Q53 - In the past, have any organizations (public or private) approached your organization to request information about your signals or related traffic measurements?

Q54 - In the last year, which of the following groups have approached your organization to request this information? Select all that apply. - Selected Choice



Q44 - Please enter any additional comments you have below.

Please enter any additional comments you have below.
Steele County has had a significant turnover of engineering staff in the past year. We have really little information on the signals other than that we have a maintenance agreement with the City of Owatonna to maintain the signals, including a few signals entirely owned by the County and outside the City limits. The answers above are best guesses as to what we know about the system so far.
If the City of Inver Grove Heights had a larger number of signals we would be more likely to need the type of information you mention in this survey.

APPENDIX C
SURVEY FOR DESIGNERS, MODELERS, AND PLANNERS

Identifying Information

As part of a MnDOT-sponsored project, the University of Minnesota is evaluating the options and best practices for implementation of a Central Traffic Signal Database to allow greater interoperability between signal owners and those who regularly need detailed intersection control information for their work, such as traffic modelers and planners.

To inform this effort, researchers are surveying traffic modelers, planners, and others who use this information to determine what kind of information they typically need and how they use it. In addition to this, researchers are also surveying signal owners and operators to determine what kind of information they collect about their signals and how this information is stored. Together, the results of these surveys will be used to help develop a unified set of intersection control information that is feasible to collect and that satisfies the needs of various applications.

This survey is meant to be open-ended to collect information about the wide variety of activities that require traffic signal control information. Please answer the questions to the best of your ability and give any information you feel is relevant, even if it is not explicitly mentioned.

Once the survey results have been collected, researchers will select a small number of participants to interview to obtain more details regarding their current practices and needs. Your responses below will be used to determine if you should be included in these interviews.

If you have any questions regarding the survey or this research, please contact mtolab@umn.edu or kevin.schwartz@state.mn.us for more information.

This survey should take less than 15 minutes to complete. Your participation is greatly appreciated.

What is your name and title/role?

What organization, agency, municipality, or company do you represent?

What level(s) of jurisdiction does your organization serve? Select all that apply.

- ☐ State
- ☐ County
- ☐ City

What transportation design, modeling, or planning activities are you involved in? Select all that apply.

- ☐ Travel demand modeling
- ☐ Traffic simulation
- ☐ Signal design and optimization
- ☐ Construction project planning/coordinating
- ☐ Work zone traffic control planning
- ☐ Transit planning
- ☐ General transportation planning
- ☐ Traffic impact studies
- ☐ Intersection Control Evaluation (ICE)
- ☐ Roadway design
- ☐ Other (please specify)

Travel Demand Modeling Programs

Do you use any of the following travel demand modeling programs that require traffic control information from intersections? Select all that apply. Please provide the version used in the adjacent text box.

- ☐ Cube
- ☐ PTV Visum
- ☐ TransCAD
- ☐ Emme
- ☐ Other (please specify)
- ☐ I don't use any travel demand modeling programs

What intersection control information (e.g. signal timing, geometric data, etc.) do the programs you selected require? Select all that apply.

- ☐ General (signal owner/operator, communication capabilities, date of last traffic control information update)
- ☐ Control Type (timed, semi-actuated, fully-actuated, priority/preemption)
- ☐ Program and schedule
- ☐ Coordination
- ☐ Timing
- ☐ Detector Phase
- ☐ Detector Locations
- ☐ Intersection Geometry
- ☐ Intersection Geo-Location Information
- ☐ Traffic Measurements
- ☐ All of the above
- ☐ Other (please specify)

Please provide a brief description of the program(s) you use and how they use this information.

Signal Design and Optimization Programs

Do you use any of the following signal design and optimization programs that require traffic control information from intersections? Select all that apply. Please provide the version used in the adjacent text box.

- ☐ Synchro
- ☐ PTV Vistro
- ☐ PASSER
- ☐ Other (please specify)
- ☐ I don't use any signal design and optimization programs

What intersection control information (e.g. signal timing, geometric data, etc.) do the programs you selected require? Select all that apply.

- ☐ General (signal owner/operator, communication capabilities, date of last traffic control information update)
- ☐ Control Type (timed, semi-actuated, fully-actuated, priority/preemption)
- ☐ Program and schedule
- ☐ Coordination
- ☐ Timing
- ☐ Detector Phase
- ☐ Detector Locations
- ☐ Intersection Geometry
- ☐ Intersection Geo-Location Information
- ☐ Traffic Measurements

☐ All of the above

☐ Other (please specify)

Please provide a brief description of the program(s) you use and how they use this information.

Traffic Simulation Programs

Do you use any of the following traffic simulation programs that require traffic control information from intersections? Select all that apply. Please provide the version used in the adjacent text box.

☐ CORSIM

☐ Vissim

☐ SimTraffic

☐ Aimsun

☐ Transmodeler

☐ DynasT/DynaStudio

☐ Highway Capacity Software

☐ Roundabout Modeling Software (e.g. Sidra, Rodel)

☐ Other (please specify)

☐ I don't use any traffic simulation programs

What intersection control information (e.g. signal timing, geometric data, etc.) do the programs you selected require? Select all that apply.

- [ ] General (signal owner/operator, communication capabilities, date of last traffic control information update)
- [ ] Control Type (timed, semi-actuated, fully-actuated, priority/preemption)
- [ ] Program and schedule
- [ ] Coordination
- [ ] Timing
- [ ] Detector Phase
- [ ] Detector Locations
- [ ] Intersection Geometry
- [ ] Intersection Geo-Location Information
- [ ] Traffic Measurements
- [ ] All of the above
- [ ] Other (please specify)

Please provide a brief description of the program(s) you use and how they use this information.

Other Programs Used

Do you use any other programs that require traffic control information from intersections? Please list the programs and the version used.

What intersection control information (e.g. signal timing, geometric data, etc.) do these programs require? Select all that apply.

- ☐ General (signal owner/operator, communication capabilities, date of last traffic control information update)
- ☐ Control Type (timed, semi-actuated, fully-actuated, priority/preemption)
- ☐ Program and schedule
- ☐ Coordination
- ☐ Timing
- ☐ Detector Phase
- ☐ Detector Locations
- ☐ Intersection Geometry
- ☐ Intersection Geo-Location Information
- ☐ Traffic Measurements
- ☐ All of the above
- ☐ Other (please specify)

Please provide a brief description of the program(s) you use and how they use this information.

General Signal Information

Regardless of the method of use, do you need the following information regarding an intersection? Select all that apply.

- [ ] Signal owner/operator
- [ ] Communication capabilities (i.e. connection to a network)
- [ ] Date of last traffic control information update
- [ ] Intersection geo-location

How would you prefer to have this information delivered?

- ○ Online Information System
- ○ File Repository (e.g. FTP with files from specific programs)
- ○ Email or other manual communication
- ○ In a format directly readable by a program I use (please specify) ________
- ○ Other (please specify) ________

Please elaborate on the use of this information.

Intersection Geometry

Do you need the following information relating to intersection geometry? Select all that apply.

- [ ] Detector locations
- [ ] Detector-phase assignments
- [ ] Number of lanes, number of approaches, number of lanes per approach

- [ ] Lane width
- [ ] Turn lanes/shared turn lanes
- [ ] Storage/taper lengths
- [ ] Intersection width
- [ ] Presence and geometry of crosswalk
- [ ] Posted speed limit
- [ ] Signal as built
- [ ] Other (please specify) ______

How would you prefer to have this information delivered?

- ○ Online Information System
- ○ File Repository (e.g. FTP with files from specific programs)
- ○ Email or other manual communication
- ○ In a format directly readable by a program I use (please specify) ______
- ○ Other (please specify) ______

Please elaborate on the use of this information.

______

Signal Control Information

Do you need any of the following information regarding the control of an intersection? Select all that apply.

- [ ] Type of coordination (for coordinated signals)
- [ ] Program schedule
- [ ] Type of control (pre-timed, semi-actuated, fully-actuated, presence of transit priority or emergency vehicle preemption, etc.)

- [ ] Additional Features, e.g. Transit Signal Priority (TSP) or Emergency Vehicle Preemption (EVP)
- [ ] Signal timing information
- [ ] Offsets (for coordinated signals)
- [ ] Protected/permissive movements
- [ ] Turn arrows, Flashing Yellow Arrow (FYA), right turn overlap
- [ ] Movement restrictions or time-of-day restrictions (e.g. no U-turns, no left turns during peak periods)
- [ ] Other (please specify)

How would you prefer to have this information delivered?

- ○ Online Information System
- ○ File Repository (e.g. FTP with files from specific programs)
- ○ Email or other manual communication
- ○ In a format directly readable by a program I use (please specify) ______
- ○ Other (please specify) ______

Please elaborate on the use of this information.

______

Traffic Measurements

Do you need any of the following historical traffic measurements collected from intersections? Select all that apply.

- [ ] Counts
- [ ] Turning counts
- [ ] Pedestrian activations
- [ ] Other (please specify) ______

Do you ever need real-time traffic measurements from intersections?

- ○ Yes
- ○ No

What level of resolution/aggregation do you typically prefer for this data?

- ○ Individual actuations
- ○ Aggregated in intervals of 15 minutes or less
- ○ Aggregated hourly
- ○ Other

Please elaborate on the use of this information.

Deliverables/Information Produced

Do you ever produce deliverables that contain intersection control information (e.g. signal timing, geometric data, etc.) for implementation by a signal owner/operator?

- ○ Yes
- ○ No

What intersection control information do you typically provide in these deliverables? Select all that apply.

- ☐ Intersection geometry information (e.g. locations of new or moved detectors)

- ☐ Individual signal program information (e.g. program schedule, timing information, etc.)
- ☐ Coordinated signal program information (e.g. offsets, etc.)
- ☐ Other (please specify)

In what format is this information typically delivered? Check all that apply.

- ☐ Synchro or other software (please provide name and version)
- ☐ Spreadsheets, CSV, other exported formats
- ☐ GIS
- ☐ PDF files of digital documents
- ☐ PDF files of scanned documents
- ☐ Construction plans
- ☐ Paper records
- ☐ Other (please specify)

Why is this format used? If a digital format (not including PDFs) is not used, would it be difficult to digitize the information produced in the future?

Other Information

Is there any other information related to traffic signals that you need or would find useful to have? If so, please describe below along with how you would use this information.

Please enter any additional comments you have below.

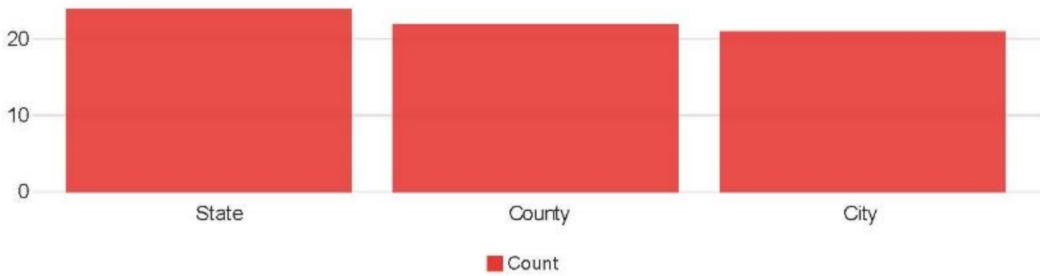
Powered by Qualtrics

APPENDIX D
RESPONSE DATA FROM DESIGNERS, MODELERS, AND PLANNERS SURVEY

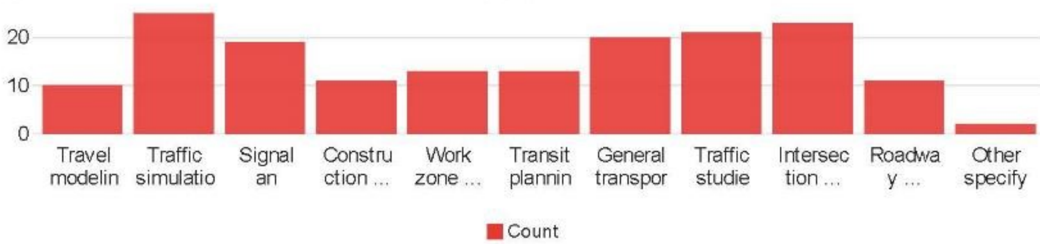
Q3 - What organization, agency, municipality, or company do you represent?

What organization, agency, municipality, or company do you represent?
Alliant Engineering, Inc.
SEH
SRF Consulting Group, Inc.
MnDOT
MnDOT - Metro Traffic
Spack Consulting
Wenck
Kimley-Horn and Associates
SRF Consulting Group
Anoka County Highway Department
MnDOT - Metro District
SRF Consulting Group
SRF Consulting
SRF Consulting Group, Inc.
SEH
SRF Consulting Group
Alliant Engineering
Bolton & Menk
Alliant Engineering
SEH Inc.

Q5 - What level(s) of jurisdiction does your organization serve? Select all that apply.



Q7 - What transportation design, modeling, or planning activities are you involved in? Select all that apply. - Selected Choice



Q7_7_TEXT - Other (please specify) - Text

Other (please specify) - Text
Interstate Access Reports (IAR)
Ped & Bike

Q24 - Do you use any of the following travel demand modeling programs that require traffic control information from intersections? Select all that apply. Please provide the version used in the adjacent text box. - Selected Choice

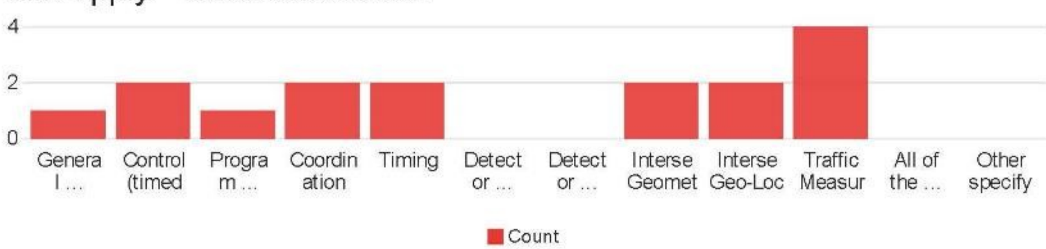
Q24_1_TEXT - Cube - Text

Cube - Text
6.4
Unsure

Q24_5_TEXT - Other (please specify) - Text

Other (please specify) - Text
DynuStudio

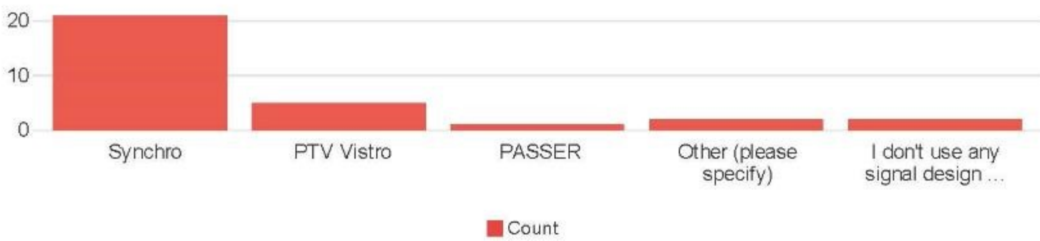
Q34 - What intersection control information (e.g. signal timing, geometric data, etc.) do the programs you selected require? Select all that apply. - Selected Choice



Q27 - Please provide a brief description of the program(s) you use and

Please provide a brief description of the program(s) you use and how they use this information.
The regional activity based model does not include any intersection data currently. Our DynusT model has the capability to include Control type and timing, however, we currently are not including those inputs.
Used CUBE in the past for TCRTDM model and transportation planning.
DynuStudio - Higher level analysis, only essentially need phase numbers, splits, and if running in coordination.
I use Cube. I don't think MetCouncil model has a lot of detail at the intersection level.
Not used in CUBE, since models have been link based information. Have employed signal timing information in the past with CUBE models but difficulty in keeping up with any changes ended up making the maintenance of the models infeasible.
The above information is used to calibrate the cube model to provide realistic capacity and delays at intersections.

Q38 - Do you use any of the following signal design and optimization programs that require traffic control information from intersections? Select all that apply. Please provide the version used in the adjacent text box. - Selected Choice



Q38_1_TEXT - Synchro - Text

Synchro - Text
version 9 or greater
9
9.2
9
Version 9 and 10
Version 9

10
9
10
9/10

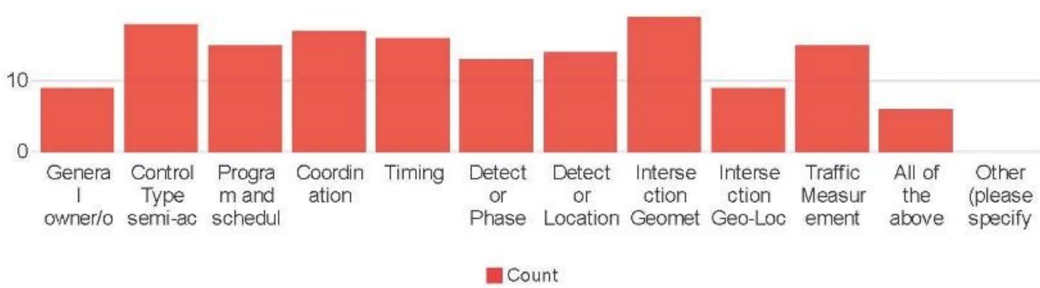
Q38_2_TEXT - PTV Vistro - Text

PTV Vistro - Text
6
6
5

Q38_6_TEXT - Other (please specify) - Text

Other (please specify) - Text
PTV VISSIM
TRU-TRAFFIC

Q39 - What intersection control information (e.g. signal timing, geometric data, etc.) do the programs you selected require? Select all that apply.



Q40 - Please provide a brief description of the program(s) you use and how they use this information.

Please provide a brief description of the program(s) you use and how they use this information.

synchro, simtraffic, vissim. require lane geometrics, signal phasing, controller operation and timing parameters. all information we compile into UTDF formats for transferring and ease of testing scenarios

All of the above information is critical to the success of accurately calibrating traffic models to existing conditions.

Synchro is used for ICE reports to get signal and stop sign MOEs. It is also used to develop future signal timing patterns for import into VISSIM or CORSIM models.

We use PTV Vistro and Synchro. These programs use timing inputs, roadway geometry, detector information, coord information to model delays using HCM calculations.

We default our use to Synchro for 90% of traffic analyses. Generally the base timings with detector and phase information is sufficient.

We use Synchro/SimTraffic and VISSIM to model arterial and freeway operations. For arterial operations we include all details relevant to traffic signal operation. For models looking at transit signal priority (TSP) we also incorporate information on TSP and Preemption related settings to ensure we are accurately replicating this info in our VISSIM model, which uses controller software (Econolite and others) embedded in the model.

I typically use Synchro and other internal MnDOT data platforms, especially loop detector data.

Synchro uses all of the above information for signal timing and coordination optimization projects.

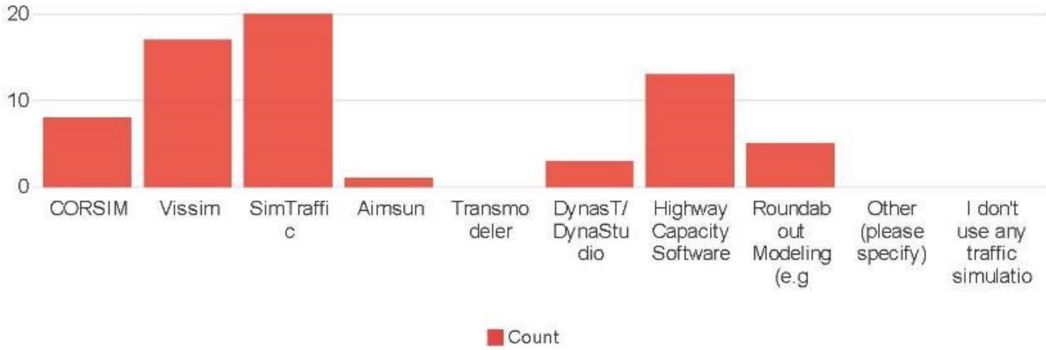
Synchro - Need to understand TOD to know what plans to enter into Synchro. Depending on the type of analysis, exact detector locations may or may not be needed. VISTRO - Similar to Synchro

We typically use Synchro for our intersection analysis. We input the above information into AM/MD/PM peak hour models to test existing conditions and validate and/or calibrate. Future conditions would keep most of the information the same but would allow for improvements to phasing or timings.

Traffic evaluation to determine LOS, delays, queues, etc.for existing and future conditions.

Synchro is the primary program since most agencies have Synchro models built and have timing plans in Synchro. Use information to develop models and calibrate so can understand which changes to implement or to understand existing operations. Signal timing and analysis.

Q35 - Do you use any of the following traffic simulation programs that require traffic control information from intersections? Select all that apply. Please provide the version used in the adjacent text box. - Selected Choice



Q35_1_TEXT - CORSIM - Text

CORSIM - Text
6.3
6.2

Q35_2_TEXT - Vissim - Text

Vissim - Text
10
10.9
8
9-14
10
10
9
10

Q35_10_TEXT - SimTraffic - Text

SimTraffic - Text
9
9.2
9
10
9 and 10
9
9
9
10
9
10

Q35_5_TEXT - DynasT/DynaStudio - Text

DynasT/DynaStudio - Text
DynuStudio Pro 1.12

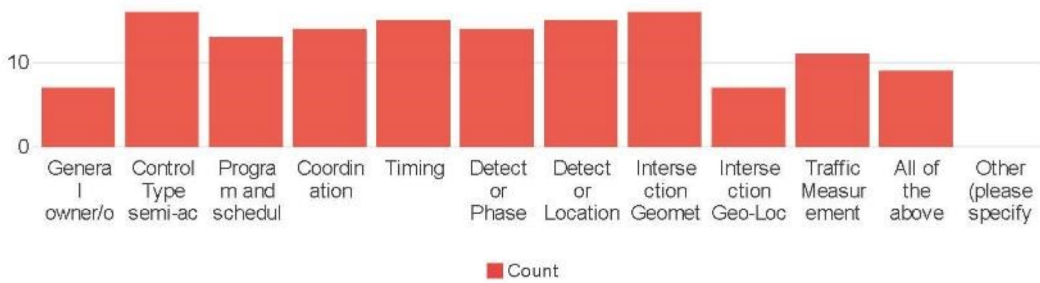
Q35_7_TEXT - Highway Capacity Software - Text

Highway Capacity Software - Text
2010, 7
7.5
6
2010
2010
7

Q35_8_TEXT - Roundabout Modeling Software (e.g. Sidra, Rodel) - Text

Roundabout Modeling Software (e.g. Sidra, Rodel) - Text
Arcady

Q36 - What intersection control information (e.g. signal timing, geometric data, etc.) do the programs you selected require? Select all that apply.



Q37 - Please provide a brief description of the program(s) you use and how they use this information.

Please provide a brief description of the program(s) you use and how they use this information.
Vissim/SimTraffic. need the details and specific information for all items listed above for most accurate analysis.
DynusT does have some control Type inputs although we currently use defaults or don't use.
VISSIM and CORSIM are used for IARs and use the signal timings at interchanges to get the traffic pulses on entry ramps. VISSIM is also used for BRT and LRT studies as it has the ability to mimic the actual signal controllers. SimTraffic and HCS are used for ICE reports.
These software packages are much like their partner programs (Vistro/Synchro) but take into account interactions between intersections.
For each program, detailed signal information is needed to ensure accurate modeling of existing conditions. For VISSIM this allows for faster and better calibration, which ultimately leads to a better model and results.
Same as previous - We use Synchro/SimTraffic and VISSIM to model arterial and freeway operations. For arterial operations we include all details relevant to traffic signal operation. For models looking at transit signal priority (TSP) we also incorporate information on TSP and Preemption related settings to ensure we are accurately replicating this info in our VISSIM model, which uses controller software (Econolite and others) embedded in the model.
I use MnDOT's Data Extract tool: http://data.dot.state.mn.us/datatools/dataextract.html

Vissim and Simtraffic typically require or use all of the above information for projects. Typically do not use programming or schedule for projects outside of specific TOD retimimg projects for agencies. HCS does not typically require geolocation, programming and schedule, or general information.

VISSIM - Need to code in all of the above for the signal controllers to operate within the program. Being able to have access to the database files of the signal controller would be helpful when we're doing detailed controller operations and using software-in-the-loop (SIL) SimTraffic - Similar to Synchro CORSIM - Similar to Synchro DynuStudio - Need to understand phase splits and which phase corresponds to each movement

We input the above information into AM/MD/PM peak hour models to test existing conditions and validate and/or calibrate (for all models). Rodel is the exception as it is only for roundabouts which have no signal timing information; if queue cutter signals, or other, are considered we would use VISSIM. Future conditions would keep most of the information the same but would allow for improvements to phasing or timings, we typically have a synchro model of every project we use to tweak timings and then input into these simulation models.

Traffic evaluation to determine LOS, queues, delays, overall circulation, etc.for existing and future conditions.

Use data to calibrate to existing conditions. Understand changes and if there is a need for changes.

VISSIM utilizes detailed signal timing information to make the models as realistic as possible. VISSIM can also run signal timing directly from ASC2/3 controllers.

Q41 - Do you use any other programs that require traffic control information from intersections? Please list the programs and the version used.

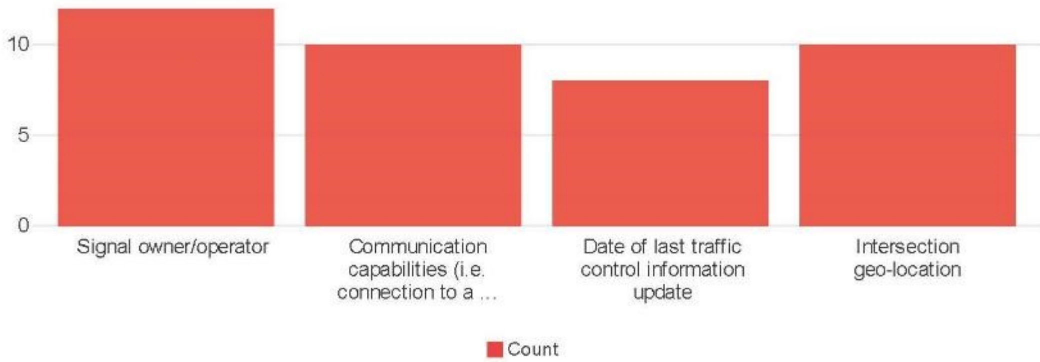
Do you use any other programs that require traffic control information from intersections? Please list the programs and the version used.

no

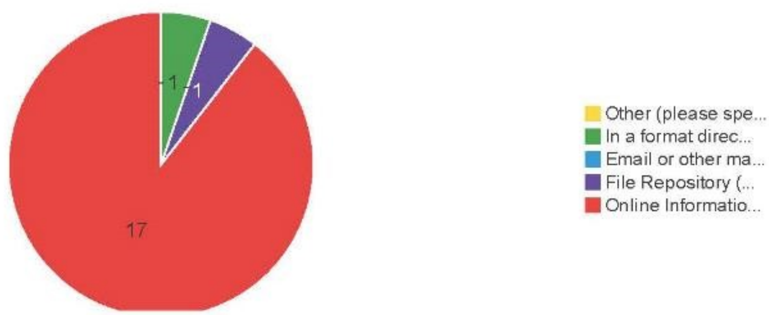
no other programs are used.

NA

Q8 - Regardless of the method of use, do you need the following information regarding an intersection? Select all that apply.



Q9 - How would you prefer to have this information delivered? - Selected Choice



Q9_6_TEXT - In a format directly readable by a program I use (please specify) - Text

In a format directly readable by a program I use (please specify) - Text
Synchro

Q10 - Please elaborate on the use of this information.

Please elaborate on the use of this information.
ultimately we obtain the agency information and compile it into UTDF or other file formats for ease of use within our own templates or modeling setup

The geo-location allows for more accurate geometrics in the models. The owner/operator is good to have if questions about the timings occur when entering them into the models.

Having a database of signal information online would be very handy and save time for almost all projects

Most of the day to day software that I use, Synchro data can be imported into the software in some way. In most cases an online database that was comprised of a Synchro model for all intersections would be the most ideal. Models could be broken down by jurisdiction and location. Within each jurisdiction a unique intersection number could be used, allowing for each updates to the Synchro models.

It would be best to have all metro signals on the same ATMS (MaxView, Centracs or other), and to have access to go in and pull data. MaxView is not best due to the fact that Econolite database files can not be retrieved, like they can be using Centracs. We use the database files when building VISSIM models, since the software reads the database files directly.

An interactive map would be ideal.

GIS online mapping of signals is not typically available foe public use, but even for agencies themselves i could see great potential for reaponding to requests for information or providing trusted powere users secure access to the GIS map and read only data.

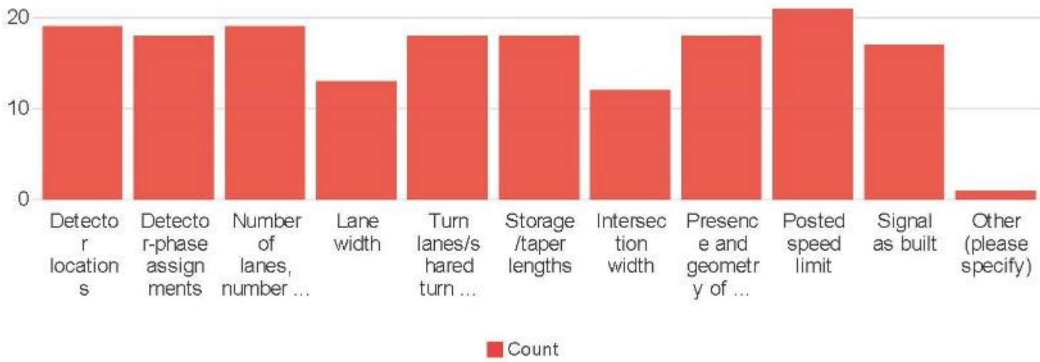
up to date database online seems to be best and easiest to update across the whole system.

Most of the work I do is planning level and only use existing information for existing/calibration of model. So the owner, communication, and last updated timings are really no concern for me. I assume the "geo-location" is just the X-Y coordinates....which we really don't need to be given to us as we would pull from an aerial or other background image.

any data is better. Synchro files would be preferred but also want pdfs of the information and timings.

An online information system or FTP site with signal timing information would eliminate requesting signal timing files every project. This would be a great way to keep files up to date and make sure users of the data have access to information for projects.

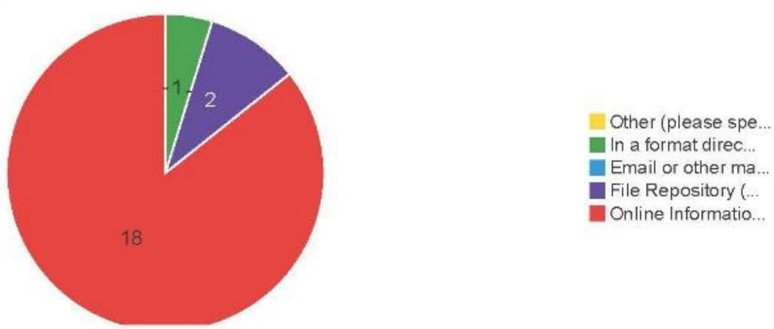
Q11 - Do you need the following information relating to intersection geometry? Select all that apply. - Selected Choice



Q11_4_TEXT - Other (please specify) - Text

Other (please specify) - Text
Most of this is found on the as built

Q12 - How would you prefer to have this information delivered? - Selected Choice



Q12_7_TEXT - In a format directly readable by a program I use (please specify) - Text

In a format directly readable by a program I use (please specify) - Text
Synchro input CSV

Q13 - Please elaborate on the use of this information.

Please elaborate on the use of this information.

All of this is required information for coding the geometrics into model.

We use this info to make sure detection is set up properly in the model, and to make sure phase directions are accurate. It is usually impossible to verify the accuracy of this info without making a site visit. Google street view may or may not be current, and phasing could always be flipped. Nevertheless, having the info is a great first step.

Ideally, it would be nice to get this from an interactive map and/or GIS

GIS link to as builts?

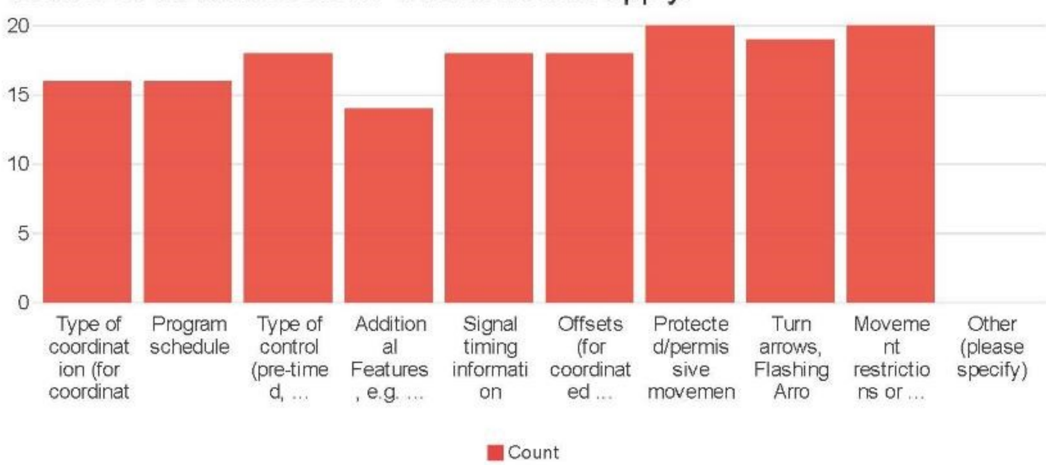
see last

If all of that information could be coded into a CSV for input directly into synchro it would be a huge time saver. However, just having access to a database that would provide the information in a clear manner and standard format would be huge!

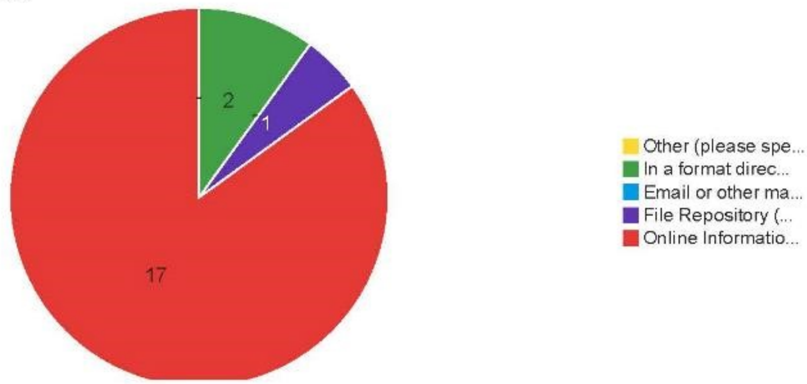
Most of the information can be readily collected at the time of a study such as turn lanes, number of lanes, lane width, etc. Information on underground equipment is not readily available using Google Maps or a field walk. Of course more data is better, especially if using for data analytics.

More information is better as far as intersection geometry. All of the above is useful but the information checked is most important.

Q14 - Do you need any of the following information regarding the control of an intersection? Select all that apply.



Q15 - How would you prefer to have this information delivered? - Selected Choice



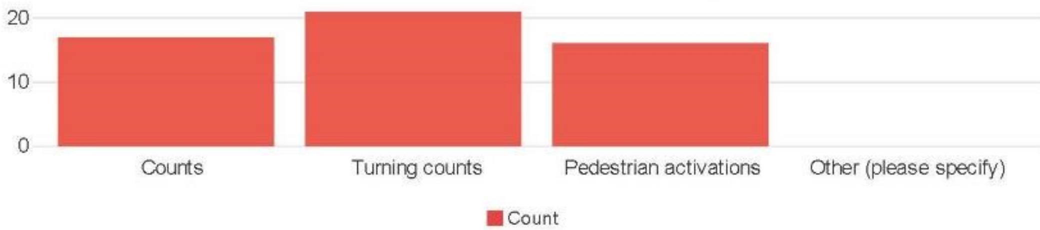
Q15_7_TEXT - In a format directly readable by a program I use (please specify) - Text

In a format directly readable by a program I use (please specify) - Text
Synchro
Synchro CSV

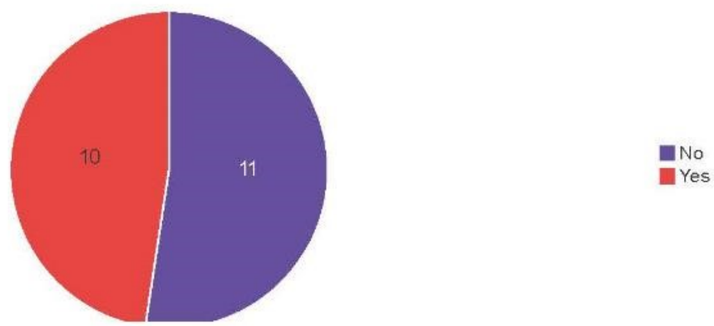
Q16 - Please elaborate on the use of this information.

Please elaborate on the use of this information.
Some of the models that are used do not need all of the information checked. Others, such as VISSIM, do have the ability to model everything listed above. With VISSIM becoming the go to model due to it's abilities to model complex situations, this information is good to have.
All of this info is essential for signal timing optimization projects.
Timing data is not as static as geometery, wonderimg about feasibility again of online GIS of timing plans, especially as many are recorded only in the contoller themselves and not connected to the internet.
see last
If all of that information could be coded into a CSV for input directly into synchro it would be a huge time saver. However, just having access to a database that would provide the information in a clear manner and standard format would be huge!
Excel spreadsheet or database for use in multiple programs preferred.

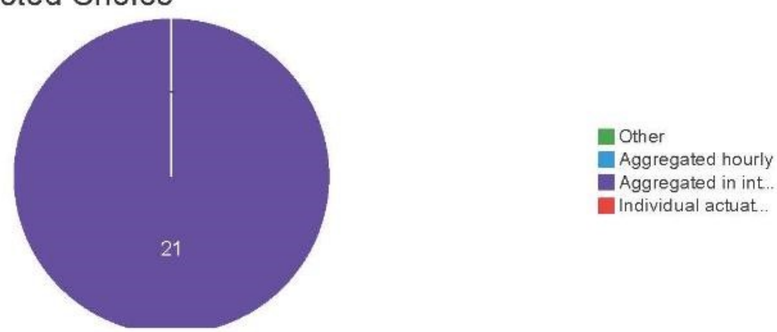
Q19 - Do you need any of the following historical traffic measurements collected from intersections? Select all that apply. - Selected Choice



Q44 - Do you ever need real-time traffic measurements from intersections?



Q22 - What level of resolution/aggregation do you typically prefer for this data? - Selected Choice



Q23 - Please elaborate on the use of this information.

Please elaborate on the use of this information.

Models are typically built using 15 minute time periods. Turn counts are a vital part of any modeling effort. Ped activations counts are sometimes needed to test their effects on the flow of traffic, particularly around bus/lrt stations.

Typically we like 15 minute counts. Having multiple weeks of 7-day data is best. We use the data to build the Synchro and VISSIM models. We are usually trying to model average/typical conditions.

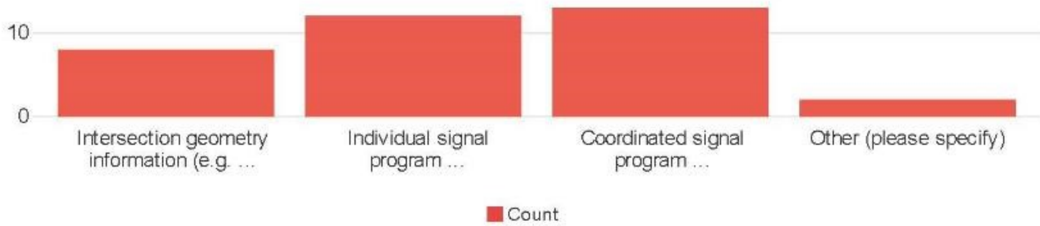
We typicall count or check if counts available within last 3 years. Real time data difficult to process for smaller trffic impact studies.

I don't necessarily need real-time information, but if it's available it would be useful in review and calibration of models after things are developed. As for count data, we typically would just use the most recent data but historical information is good to have in case of questionable data or big imbalances between intersections.

More for calibration and understanding of what is happening and why.

Q27 - Do you ever produce deliverables that contain intersection control information (e.g. signal timing, geometric data, etc.) for implementation by a signal owner/operator?

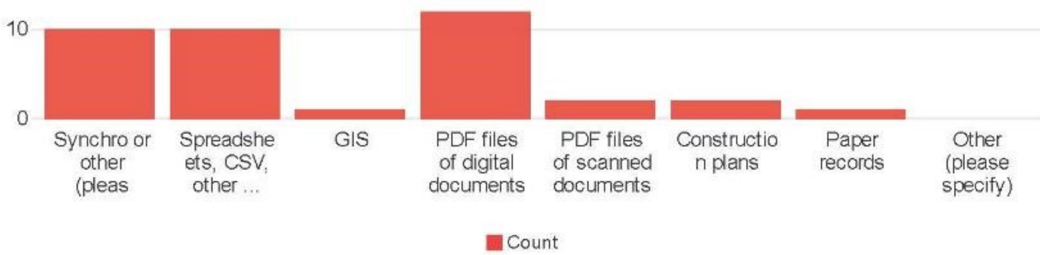
Q28 - What intersection control information do you typically provide in these deliverables? Select all that apply. - Selected Choice



Q28_4_TEXT - Other (please specify) - Text

Other (please specify) - Text
programming sheets
TSP timings, preemption

Q30 - In what format is this information typically delivered? Check all that apply. - Selected Choice



Q30_1_TEXT - Synchro or other software (please provide name and version) - Text

Synchro or other software (please provide name and version) - Text
Synchro

Q31 - Why is this format used? If a digital format (not including PDFs) is not used, would it be difficult to digitize the information produced in the future?

Why is this format used? If a digital format (not including PDFs) is not used, would it be difficult to digitize the information produced in the future?
can be time consuming to compile all the digitial information, depending on format and purpose
PDF form is added to controllers and provided to the agency
Synchro is used, because it allows the agency to update their base model by uploading the new timing information with the Synchro importer function.
Deliverables are per agency request. Different agencies require different deliverables. Some agencies want Synchro, some don't use Synchro. Some want lots of details, others fewer. Some want spreadsheets, some don't mind PDFs. Some want to take the deliverables and implement themselves, others want us to implement.
I prefer simplistic formats that most people can understand and have access to.

Client capabilities and software ownership.

Q32 - Is there any other information related to traffic signals that you need or would find useful to have? If so, please describe below along with how you would use this information.

Is there any other information related to traffic signals that you need or would find useful to have? If so, please describe below along with how you would use this information.

none.

Access to Autoscope camera feeds would be useful. We use this for some agencies to perform remote fine-tuning of controller parameters.

For me, up to date signal timing and offsets typically the longest delay tonreceive from agencies, unless already in sychro or their own traffic signal management software

Having access to the databases running in the field.

pedestrian actuations, traffic volumes, delay, arrivals on red, coordination parameters, preempt alarms. Useful in saving time on data collection, as well as quantifying and gut-checking parameters and complaints.

I think you covered all of the information necessary.

Q33 - Please enter any additional comments you have below.

Please enter any additional comments you have below.

none.

The more agencies that would participate in a central database, the better. We would be happy to help with creation/design of the database/platform.

Thanks for researching this topic.

Ideally if all of the signal/intersection information was able to be formatted in a way that software could read it quickly, say a Synchro input CSV file, it would make a huge time savings. However, even a standardized format would make things a ton easier.....it is sometimes hard to follow some signal information as it can be a huge amount of data/pages that are not necessary, when some signal information is boiled down to 1-3 pages and easily discernible.